NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

DETERMINING THE NUMBER OF OFFICERS TO GRADUATE FROM THE NAVAL SCHOOL AND THE NUMBER OF NAVAL SCHOOL GRADUATED OFFICERS TO PROMOTE BY RANK IN ORDER TO MEET ACTUAL AND FUTURE NEEDS OF THE MEXICAN NAVY

by

Fidencio Vargas Davila

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Thesis Advisor:	Samuel Buttrey
Second Reader:	Bill Hatch

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The Mexican Navy is challenged with too few O-1 to O-3 officers and too many O-6 to O-9 officers. This research developed three models to explain the challenge. Through the use of a transition probabilities matrix, model one predicts the number of graduates from the Mexican Naval School based on accessions. Model two is a transition probability matrix that uses model one's output to forecast the distribution of Naval School Graduate Officers (NSGO) by grade over the next ten years.

Model three is a non-linear objective function that observes gaps between expected inventory and demand of NSGO over the same period. For minimizing these gaps, this model considers three alternatives. The first alternative changes some transition probabilities of the second matrix while maintaining constant the probabilities of leaving ("out" probabilities) the MN and the probability of graduating from the Naval School (NS). The second alternative also changes some "out" probabilities and maintains constant the last probability. The last alternative also changes the probability of graduating from the NS.

This research provides a method to determine the number of graduates from the NS and the numbers of promotions by grade to meet expected demands for NSGO personnel in the future.

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Vargas Davila, Fidencio
Commander, Mexican Navy
B.S., Mexican Naval School, 1986

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Author: Fidencio Vargas Davila

Approved by: S. Buttrey
Thesis Advisor

B. Hatch
Second Reader

James N. Eagle
Chairman, Department of Operations Research

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EXECUTIVE SUMMARY

According to an S-1 committee document (a Mexican Navy Staff entity, similar to the U.S. Navy J-1) after territorial commands meeting, it was concluded that the Mexican Navy (MN) requires a total of 59,403 personnel. The MN is budgeted for an authorized personnel end strength of 53,318. The S-1 recommended a reduction of 15%, to 50,492 personnel, in order to remain within budget constraints. Based on this information, the MN decided to increase its’ operational and administrative units, and naval facilities personnel end strength, from 44,641 to 48,197.

However, this increment in personnel strength did not reduce short or long term grades gaps between inventory and demand of Naval School Graduated Officers (NSGO). The S-1 document highlights that there is a large deficit of NSGO personnel among the junior officers in grades Ensign, Lieutenant Junior Grade, and Lieutenant. In contrast, S-1 observed an excess of officers personnel among the senior grades above Commander.

S-1 considers the NSGO gaps among the junior officers are due to promoting greater numbers of these personnel each year than the numbers of officers graduated from the Naval School (NS). This promotion behavior has consequently produced many vacancies (gaps) among the junior ranks and excesses among the senior grades. The S-1 has concluded that promotion rates should be based on senior Mexican Naval officer requirements and retention rates and NSGO attrition rates.

Based on the Mexican Navy’s mission and objectives it is organized in a five-level chain of command. The President represents the first level, the Supreme Command. The following four levels, High Command, Secretary of the Navy, Chief Superior Commands, Superior Commands, and Subordinate Commands, have all been occupied the last 22 years by Naval School Graduate Officers. It seems highly probable that NSGO personnel will continue to be preponderant at these levels in the short and long term.

This research first analyzed the Mexican Naval School data from 1991 to 2002 in order to determine the number of students who entered and graduated, and their survival and continuation rates. By using an average continuation rate, a probabilistic transition matrix called the Naval School Transition Probabilities Matrix (NSTPM), was built to predict the number of officers, as a function of those entering, who would graduate from the Naval School. The data showed that an average of only 31 % of officer candidates entering between 1991 and 1997 graduated from the NS. This percentage represents the probability of a student graduating from the Mexican Naval School.

Next, an analysis of NSGO personnel data from 1980 to 2002 was conducted to determine promotion, attrition and retention rates of Mexican Naval Officers. Knowing the number of officers promoted and those who left the service during the same period allowed for a computation of the probability of a NSGO being promoted by rank. These probabilities provided a foundation to build a probabilistic transition matrix, the Naval School Graduate Officer Transition Probabilities Matrix (NSGOTPM), to define the NSGO personnel promotion-attrition behavior over the last 20 years.

The result of this research was an algorithm to predict the yearly number of promotions by grade. The promotion methodology was based on NSGO personnel demand and inventory and an optimal percentage of graduates from the Naval School. This was accomplished by using a mathematical optimization model to change some of the probabilities of the NSGOTPM.

I. INTRODUCTION

A. PROBLEM

After territorial commands meeting an S-1 document concluded that the Mexican Navy (MN) requires a total of 59,403 personnel. The MN is budgeted for authorized personnel end strength of 53,318. The S-1 recommended a reduction of 15%, to 50,492 personnel, to remain within budget constraints. Based on this information, the MN decided to increase its' operational, administrative units, and other naval facilities personnel end strength, from 44,641 to 48,197; it would have 2,700 additional personnel in marginal roles, such as students, personnel deployed in other federal agencies, and etc.

This increase in MN personnel would close the gap between requirements (spaces) and personnel inventory (faces). However, this research highlights that there is a large deficit of Naval School Graduated Officers (NSGO) in the grades of Ensign, Lieutenant Junior Grade, and Lieutenant. S-1 reports that this is due to the promotion of greater numbers of officers yearly than the number of officers graduated from the Naval School (NS). This promotional behavior has produced many more vacancies among these officer grades than in the higher grades, according to S-1.

The S-1 remarked due to a lack of personnel planning we do not know the number of NSGO requirements needed at each grade, from Ensign to Lieutenant. Additionally, the inability to accurately predict grades requirements significantly impacts the Naval School. Naval School graduate requirements are based on officer attrition and retention at the junior grades. Accessions are based on retention and attrition of NS students. Ultimately all accessions and promotions affect the operational requirements for NSGO in the Mexican Navy. S-1 concludes by saying that we do not know the number of naval officers, from Ensign to Captain, we need to promote each year.

B. OBJECTIVE

The first purpose of this thesis was to analyze the Mexican Naval School data from 1991 to 2002 in order to determine the number of students who entered and graduated. This research analyzed the survival and continuation rate behavior during this period. Using an average continuation rate a probabilistic transition matrix was built to predict the number of officers, as a function of accessions, who would graduate from the Naval School.

Once the probabilistic transition matrix was built an analysis of the Naval School Graduated Officers data from 1980 to 2002 was conducted to determine promotion, attrition and retention rates of Mexican Naval Officers by grade. Knowing the number of officers promoted or who left the system during this period allowed a comparison of the probability of a NSGO being promoted by grade. These probabilities provided the foundation to build a probabilistic transition matrix to define the NSGO personnel promotion-attrition behavior over the last 20 years.

The result of this research was an algorithm to predict the yearly number of promotions by grade. The promotion methodology was based on NSGO personnel demand and inventory and an optimal percentage of graduates from the Naval School. This was accomplished by using a mathematical optimization model to change some of the probabilities of the NSGOTPM

The intent of this research is to help the Mexican Navy decision makers improve personnel promotion policies.

C. MEXICAN NAVY. DEFINITION, MISSION, ATTRIBUTES, AND ORGANIZATION

The main mission of the Mexican Navy is specified in the first article of the "Mexican Navy Organic Law" (MNOL) [Ref. 1: pp. 3-6]. This article defines the Mexican Navy as a Permanent National Military Institution that has the mission of preserving the homeland security and the exterior defense of Mexico by means of using the naval power of the federation.

Among the MN attributes (article 2, MNOL) are the followings:

- Surveillance of the territorial and exclusive economical waters.
- Search and rescue operations on the ocean and interior waters.

- Protect strategy facilities.
- Meteorological and Oceanographic research.
- Combat against terrorism activities and illegal drug traffic.

In order to meet its mission and each of its attributes the MN is organized in the following chain of command (article 9, MNOL):

- Supreme Command, President of the United States of Mexico
- High Command, Secretary of the Navy
- Chief Superior Commands, Naval Region Commands and Naval Force Commands
- Superior Commands, Naval Zone Commands and Headquarters Command
- Subordinate Commands, Warships, Marine Corps Entities and Naval Aircraft Executive Officers and other administrative units.

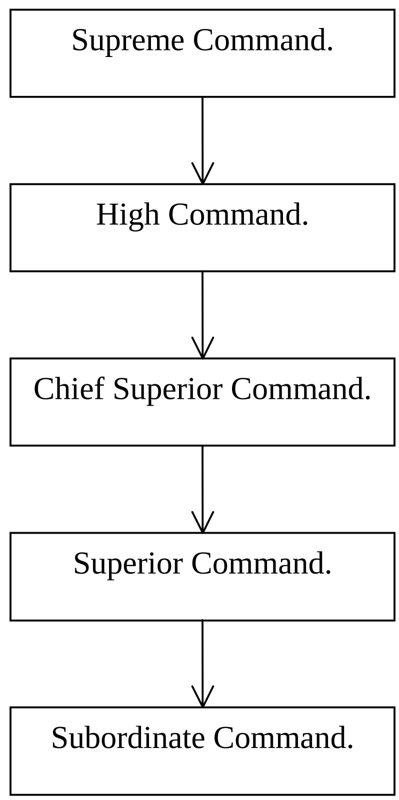

Figure 1. Mexican Navy Chain of Command.

The President as Supreme Commander appoints the High Commanders, Chief Superior Commanders, and Superior Commanders. The Secretary of the Navy appoints the Subordinate Commanders.

D. ROLE OF NAVAL SCHOOL GRADUATE OFFICERS IN THE MEXICAN NAVY

The MNOL specifies who shall be assigned to each level within the chain of command, but it does not clearly specify whether the High Command has to have the rank of Admiral (by Admiral we mean those who have the rank of Admiral, Vice Admiral, and Rear Admiral). Historically over the last 22 years the Secretary of the Navy has been an Admiral. The Chief Superior Commanders and the Superior Commanders have been designated from among the category of Admiral Personnel during the same period.

During the last 22 years the seats of the Secretary of the Navy, the Chief Superior Commands, the Superior Commands, and the Subordinate Commands (for all of the operational units) have all been occupied by Naval School Graduate Officers. Therefore it is reasonable to analyze the NSGO personnel separately even though they only represent, approximately, 5.40% of the total Mexican Navy requirements.

E. PROMOTION POLICIES

1. Promotion Process of NSGO Personnel

The promotion process of an NSGO begins after graduation from the NS, when a graduate immediately becomes a Midshipman (the first rank of officer for a NSGO). The Secretary of the Navy determines the period a NSGO remains as a Midshipman (article 5, “Midshipmen Regulation for Practices and Professional Exams” [Ref. 1: pp. 221,222]); but is not to exceed two years. Since this article does not specify a minimum time in grade (TIG), the research assumes one year as the minimum TIG of a Midshipman.

During this year the Midshipman is attached to a MN warship where he performs professional practices. His operational unit training consists of six months of deck officer duties and six months of engine officer duties. In both cases, the Midshipman is assigned as aide to the officer in charge of each area of the ship. The Midshipman is examined, in each area, at the end of each six-month period. If he passes both exams, he is promoted to Ensign; if not, he continues as Midshipman until he passes the exams.

A midshipman who fails the exams is rolled back to join the junior class. If he does not succeed in passing the exams of his new class, he may be changed to another branch of service as approved by the Secretary of the Navy. This research assumes that each Midshipman is promoted to Ensign after one-year time in grade (TIG). Figure 1 depicts the typical promotional process of an NSGO in the MN.

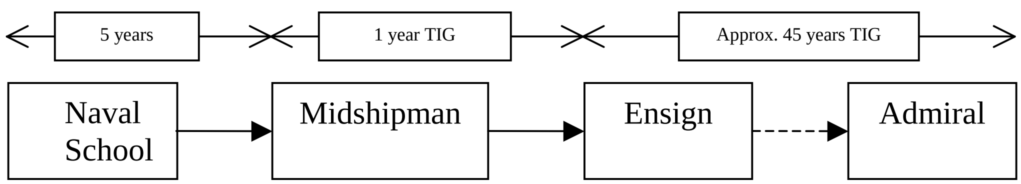

Figure 2. NSGO promotional diagram after graduating from the Naval School through Admiral.

2. Promotion Policies for Ensign Through Lieutenant Commander

Promotions from Ensign through Lieutenant Commander during peacetime are defined according to "Mexican Navy Promotions Law" (MNPL) [Ref. 1: pp. 33-39]. MNPL article 2 states that promoting a Mexican Navy Officer, from Midshipman (or equivalent ranks) through the grade of Admiral is a function of the Supreme Command in accordance with the Mexican Constitution. MNPL defines a promotion as the event of having a person ascend to the next grade. Moreover, the MNPL specifies that promotions from Ensign through Lieutenant Commander are conferred after a rigorous selection process.

The MNPL article 14 says that promotions during peacetime are in order to fulfill the MN vacancies with capable and skillful personnel who will perform duties related to those required in the next grade. Article 14 also specifies that the number of vacancies is established by the Mexican Navy Staff.

Among all the requirements that an Ensign through Lieutenant Commander must meet to satisfy consideration for promotion, the most important is at least three years TIG. However, there are special circumstances under which an officer can be promoted without observing this seniority criterion. These special circumstances are well specified in the MNPL, and will not be considered in this research. Figure 2 shows the typical process for promoting an officer from Ensign through Lieutenant Commander.

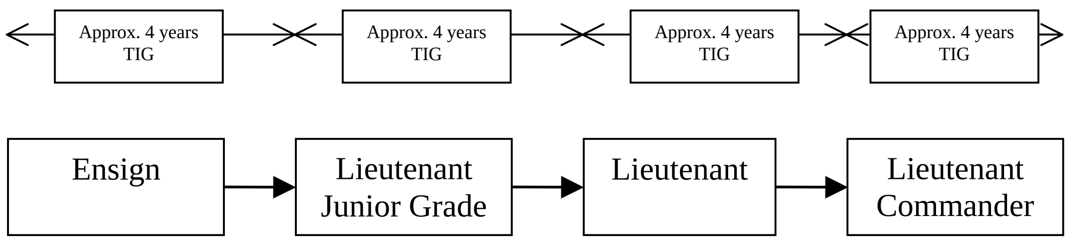

Figure 3. NSGO promotional diagram from Ensign through Lieutenant Commander.

3. Promotion Policies for Commander Through Vice Admiral

Promotion policy for Commander through Vice Admiral during peacetime are in accordance with MNLP articles 30 and 31, and are given by the Supreme Commander, President of the Mexican United States, based on section IV of article 89 of the Mexican Constitution. The main criteria for promotion, according to MNLP, are seniority, aptitude, and professional skills. However, MNLP has not established TIG for these grades prior to being considered for promotion. Figure 3 depicts the typical promotion process for Commander through Admiral.

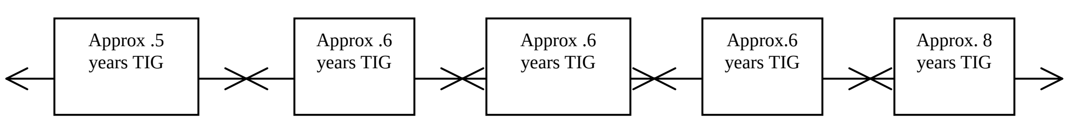

Figure 4. NSGO promotional diagram from Commander through Admiral.

F. LEAVING THE MEXICAN NAVY

For purposes of this research, personnel leaving the MN will be considered as being in an end event from which they cannot return to active duty. Personnel can leave the system under many circumstances. The following are categories of leaving: Voluntary separation (Voluntary Retirement, Attrition, or Desertion), and Involuntary separation (Forced Retirement or Death).

1. Retirement Policies

Policies for retiring personnel in the MN are found in the “Social Security Institute Law for the Mexican Armed Forces” (SSILMAF) [Ref. 1: pp. 95-100]. Retirements are either voluntary or forced. Voluntary Retirement is the result of an individual’s decision to leave the service that is approved by the MN, whereas Forced Retirement is the result of a MN decision.

Voluntary Retirement is defined by SSILMAF as the process of passing from active duty to a retirement state after serving for at least 20 years. This period of time can be the result of either 20 uninterrupted years of service or several segments of service totaling 20 years. After meeting these criteria personnel are entitled to retirement pay. Table 1 shows the salary distribution after 20 years or more of service.

These percentages apply to the base salaries; they do not apply to the special bonuses a NSGO gets paid while remaining on active duty. As an example a Commander today that has been on active duty for 22 years gets paid approximately 4,000.00 U.S. Dollars per month which is represented by 20% base salary and 80% special bonuses. If the same Commander retires today his retirement payment would be 65% of something between 800.00 and 900.00 U.S. Dollars per month.

Years of Service	Percentage of Salary
20	60%
21	62%
22	65%
23	68%
24	71%
25	75%
26	80%
27	85%
28	90%
29	95%
>30	100%

Table 1. Salary distribution for retired personnel.

In the case of Forced Retirement, personnel are retired after meeting the time in service criteria described for Voluntary Retirement. Personnel can be retired because of either meeting the mandatory age limit for each grade, see table 2, or being physically unable to perform their military duty. Personnel forced to retire are paid the same percentages showed in table 1 as those with voluntary retirements.

Table 2 shows the SSILMAF age limit for each grade for retirement.

Rank	Age Limit
Ensign	48
Lieutenant Junior Grade	50
Lieutenant	52
Lieutenant Commander	54
Commander	56
Captain	58
Rear Admiral	61
Vice Admiral	63
Admiral	65

Table 2. Age Limit Distribution for forced retirement.

2. Attrition, Desertion and Death

a. Attrition

Attrition is the separation from active service before having stayed in the MN for at least 20 years. Voluntary attrition is an event that cannot be predicted.

b. Desertion

Desertion is another way of leaving the MN, and like attrition it cannot be controlled.

c. Death

The final way of leaving the MN is death. Death, like attrition and desertion, cannot be controlled.

In summary, the event of leaving the Mexican Navy will be considered as an end event from where personnel cannot return to active duty, regardless of whether leaving the system is by means of retirement, death, attrition, or desertion.

G. THESIS ORGANIZATION

The research presented in Chapter II will discuss manpower planning. Chapter III will discuss how the Naval School Transition Probabilities Matrix (NSTPM) and the Naval School Graduated Officers Transition Probabilities Matrix (NSGOTPM) were built. The NSTPM explains the student continuation rate observed the last 11 years, whereas the NSGOTPM explains the Naval School Graduated Officers (NSGO) promotion-attrition behavior observed the last 20 years.

In addition to this, in Chapter IV a Markov model applied to length-of-service is used along with the NSTPM to predict the number of graduating students as a function of the entering number. Based on these predictions, and by using a NSGO initial stock and the NSGOTPM, an expected inventory of NSGO personnel by ranks is obtained for the next ten years. After forecasting these personnel distributions, an optimization model was built in order to reduce the discrepancies observed between expected inventory and expected demand during the same period.

Finally, in Chapter V the thesis’s conclusions and limitations, and suggestions for future research are given.

II. BACKGROUND

Controlling the composition of any armed force requires a well-defined short-term and long-term requirement for personnel. Major Suryandi (Indonesian Army) in his Master of Science in Operations Research Thesis [Ref. 2], points out the importance of having an adequate system of promotion in order to control the growth of the Indonesian Army Officer Personnel strengths. Major Suryandi applies the Grade / Time–in-Grade manpower model[1] to analyze the officer composition of the Indonesian Army. Major Suryandi shows that by using this model, manpower planners can examine different promotional policies and change parameters in order to improve the use of personnel resources in the Indonesian Army. Major Suryandi notes that with the mentioned manpower models the expected time in the organization, the promotion rate and the steady state distribution grade can be calculated. With this information, Major Suryandi concludes, manpower decision makers could control the number of Army Officers.

Professor Kneale T. Marshall's paper [Ref. 3] shows how efficient computation methods can be used with a two-characteristic model by exploiting its special underlying matrix. These methods make efficient use of a basic flow optimization model.

In his model formulation Professor Marshall assumes that manpower enters into a system on one of its K chains at some element of discrete time and is counted in one of its N grades while it remains in the system. He defines a $n \times m \;\; P(t)$ matrix with elements $P_{ij}(t)$ that are described as the fraction of manpower personnel entering grade j coming from grade i, t periods of time after joining the system. By entering a chain, Professor Marshall means joining a grade.

In his Master's Thesis [Ref. 4] U.S. Army Major Wade S. Yamada makes reference to the importance of knowing the number of officers to access, promote and separate each year. Major Yamada developed an Infinite Horizon Manpower Planning Model (IHMP), which optimizes the management of army officers. Major Yamada's

[1] W.J. Hayne and K.T. Marshall, "Two-Characteristic Markov-Type Manpower Flow Models", Naval Research Logistics Quarterly, Vol. 24, No. 2, June 1977

model determines yearly numbers of recruits, promotions, and separations in order to meet inventory targets. He considers personnel needs as an infinite planning problem for which countless techniques to approximate an infinite horizon have been developed. Major Yamada says that the technique that best fits an approximation to infinite horizon is the dual equilibrium technique. One of the Yamada's key ideas is the one that highlights the importance of the Army's Military Personnel Account. Due to the size of the Army's Military Personnel Account, predicting and controlling personnel is essential for budget planning and execution.

D. J. Bartholomew [Ref. 5; pp. 81-90] describes a stochastic model of a manpower system as a probabilistic description of the inter-relationships between the stocks and flows of manpower over time. The author adds that a model is stochastic if it describes the way the system is changing in probabilistic terms. Bartholomew affirms that stochastic models are used for forecasting to their use for control or management of manpower systems; thus, a forecast tells us what will happen to the system if present trends continue. By knowing this prediction, a control strategy can be applied in order to alter the parameters of the system over time for obtaining some desired objectives. For obtaining these objectives, first the goal is fixed and then the parameter values have to be found. A forecast, the author says, is useful to alert us to the need for action but only a theory of control can tell us how to correct the situation. Bartholomew concludes that manpower systems must been seen as a whole, in which promotion, attrition, and recruitment are all interconnected and must all be seen in the context of their relationship.

In his research [Ref. 6; pp. 183-204] A.R. Smith defines manpower planning as an approach to the management of human resources, which presupposes that if we predict the likely future we stand a better chance of making efficient use of resources. On the other hand, the author adds, if we do not think ahead systematically and quantitatively we would not be able of making efficient use of those human resources. Smith also sees the manpower planning as a process in which the likely consequences of the continuation of current policies or the introduction of new policies can be assessed, and action taken to avoid consequences, such as substantial forecasted mismatch between objectives and resources or between one kind of resources and another. The author affirms that not all changes and events can be predicted, but an organization that has effective planning can adapt more quickly to new circumstances as they arise. Smith concludes that the general aim of manpower planning is to reduce the risk of surplus or shortage, excess or deficit, of particular kinds of manpower.

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III. TRANSITION PROBABILITIES MATRICES

The first part of Chapter III describes how we computed the Mexican Naval School survival and continuation rates observed over the last eleven years that helped us build a transition probabilities matrix. The second part of the chapter explains the NSGO personnel promotion-attrition behavior observed the last 20 years by means of a transition probabilities matrix.

A. NAVAL SCHOOL TRANSITION PROBABILITY MATRIX (NSTPM)

1. The Naval School (NS) Data

The data from the Naval School (NS) was obtained from the General Director of Naval Education, Postgraduate and Professional Formation Department at Mexican Navy Headquarters, in Mexico City. This data contains information on the number of entering and graduating students from August 1991 (the entry for years 1991 and 1992 occurred in September, but since in the following years the entry occurred in August, we decided to consider all of them as occurring in August) to November 2002. The first numbers (see Appendix A) represent the entering numbers for each of the classes. The last numbers, for classes 1991 to 1997, represent the personnel who graduated after staying five years (60 months) in the NS (there were 8 International students who graduated from 1996 to 2002, who are not considered in these numbers). The final numbers for classes 1998 to 2002 show the remaining students for each class at November 2002. The remaining numbers show the surviving students, month by month, in each class. For purposes of this thesis it will assume assumed that students leaving the NS will not reenter in the same class.

The NS organizes its courses by semesters. First-semester lectures run from September to December, and second-semester lectures from February to May. During the months of January and June the semester final exams are held. July and August are for training tours at sea. Based on this information we expect to see large numbers of students leaving the system after each of the semester final exams, when the students who fail to pass their courses are dismissed from the NS.

2. The Notation

Defining the following indices:

i = class (i = 1991, 1992… 2002)

j = month (j = 2, 3… 60)

and the nonnegative integer random variables:

$X_{i,j-1,j}$ = number of students of class i who pass from month $j-1$ to month j

$Y_{i,j-1,out}$ = number of students of class i who leave the NS in month $j-1$

$X_{i,j-1}$ = number of students of class i in month $j-1$

we have the following equation:

$$X_{i,j-1,j} = X_{i,j-1} - Y_{i,j-1,out} . \qquad (3.1)$$

This equation defines the numbers of students of each class remaining month by month.

By using (3.1) we can compute the number of students in each class who leave the NS monthly by using

$Y_{i,j-1,out} = X_{i,j-1} - X_{i,j-1,j}$.

3. The Survival Rate

We define the survival rate as the fraction of students of class i who remain in the NS more than j months. Richard C. Grinold and Kneale T. Marshal [Ref. 5: pp. 101] define the survivor fraction as

> The fraction of people who remain in the organization more than u periods [of time]

Based on these definitions for survival rate (or survival fraction), we define its mathematical expression as follows:

$$SR_{i,j-1} = \frac{X_{i,j-1}}{X_{i,1}} \text{, where} \qquad (3.2)$$

$SR_{i,j-1}$ = fraction of students of class i who stay in the NS in month $j-1$

$X_{i,j-1}$ = number of students of class i in month $j-1$

$X_{i,1}$ = number of students of class i who entered the NS.

For example, we would compute $SR_{1991,2}$ as $\frac{X_{1991,2}}{X_{1991,1}}$, which is equal to $\frac{135}{149}$ = 0.9060. The rest of the survival rate computations for each class i, in each month $j-1$, are similar. In order to speed these computations we use Excel. Appendix B shows the survival rate for each class. We round the results to two decimal places. Thus, $SR_{1991,2}$ changes from $SR_{1991,2}$ = 0.9060 to $SR_{1991,2}$ = 0.91. The same rounding criteria are applied to each result.

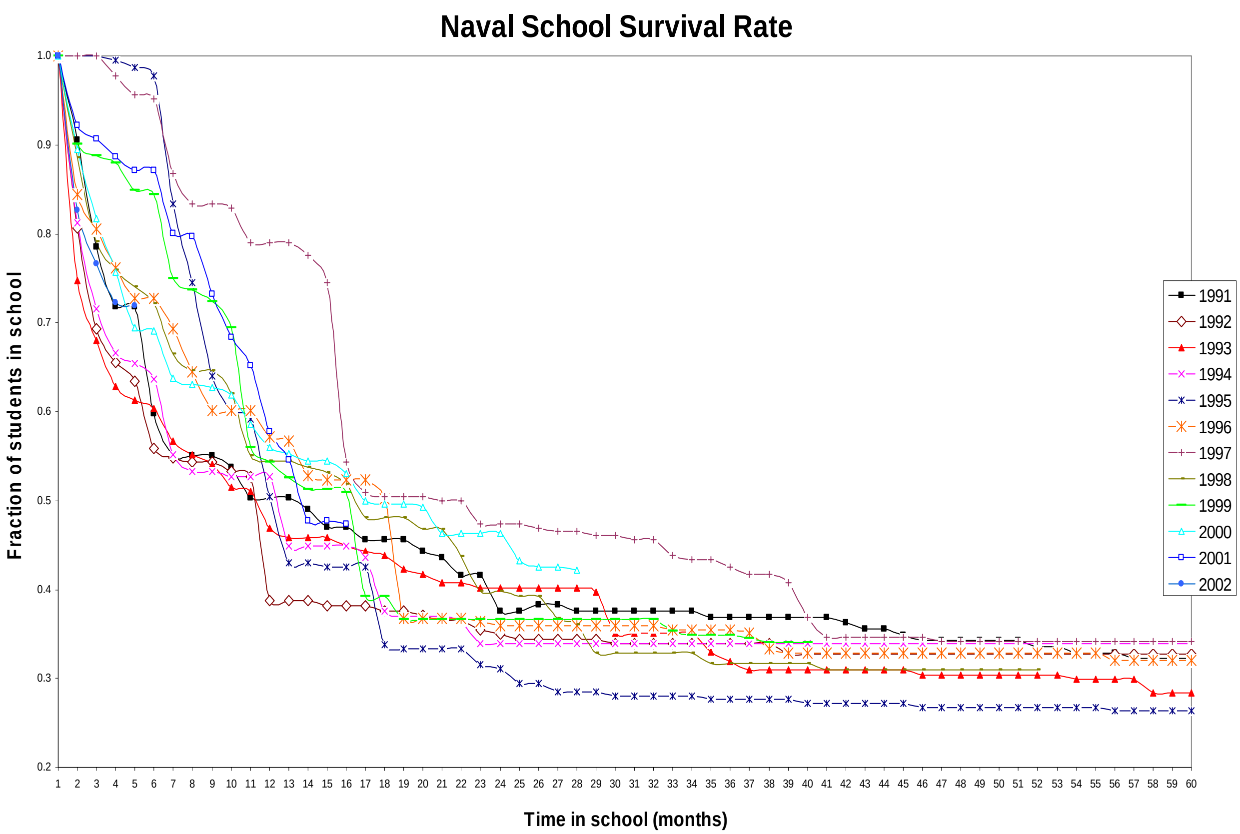

Figure 5. Naval School Survival Rate

The above graph shows the survival rate of each class i observed month by month j. We can see that the average number of students graduating from the NS, years 1991 through 1997, ranges from 26% to 34%. The minimum value is observed in class 1995, and the maximum value in classes 1994 and 1997.

This research focuses on the average NS graduating students. The data used for this research represents classes 1991 to 1997. It represents the number of entering and graduating students, in order to compute a weighted average survival rate estimator. Weighted averages were used instead of simple averages because the starting sizes large variability in each class. When using weighted average, we assign a weight to each $X_{i,j-1}$ value that is proportional to its relative importance during the computation.

The following equation depicts research method of computing the weighted average survival rate:

$$WAvSR_{i,j-1} = \frac{\sum X_{i,j-1}}{\sum X_{i,1}} \tag{3.3}$$

for i = 1991, 1992, 1993, 1994, 1995, 1996, 1997

and j = 2, 3, 4, 5… 60

where:

$WAvSR_{i,j-1}$ = fraction of students of class i who stay in the NS in month $j-1$

$\sum X_{i,j-1}$ = number of students of class i in month $j-1$

$\sum X_{i,1}$ = number of students of class i who entered the NS.

In this particular case, each $X_{i,j-1}$ value by itself represents its relative importance in the computation of weighted average. On the other hand, the summation symbol $\sum$ is used without designating its index i or the values for the index. What this means is that the summation is for all the values of $X_{i,j-1}$ in the numerator and $X_{i,1}$ in the denominator.

Suppose we want the weighted average survival rate in month 2. By using 3.3, for i = 1991, 1992, 1993, 1994, 1995, 1996, 1997, and j =3, we would have:

$$WAvSR_{i,2} = \frac{\sum X_{i,2}}{\sum X_{i,1}}$$

After substituting the corresponding values from the Appendix A's table, we have the following:

$WAvSR_{i,2} = \dfrac{135+150+145+134+228+195+228}{149+186+194+165+228+231+228} = 0.88$ (after rounding to two decimal places).

The rest of the computations are done similarly. After using Excel for doing the computations, and rounding to two decimal places, we obtain the table in Appendix C which shows in the $WAvSR$ column the weighted average survival rates of classes 1991 through 1997, from month 1 to month 60. We conclude from Appendix D that we may expect about 31% of the students entering classes 1998 through 2002 to be graduated from the NS.

4. The Continuation Rate

The continuation rate is defined as the fraction of the entering students of each class who stay in the NS month by month. Grinold and Marshal [Ref. 5: pp. 135] define the continuation rate as

> The fraction of people …who continue to be in the system and appear one period [of time] later [in the system].

a. Mathematical Equations

According to the above definitions for continuation rate (or continuation fraction), we have the following mathematical expression:

$$CR_{i,j-1,j} = \frac{X_{i,j-1,j}}{X_{i,j-1}}, \text{ where} \tag{3.4}$$

$CR_{i,j-1,j} =$ fraction of students of class i who pass from month $j-1$ to month j

$X_{i,j-1,j}$ = number of students of class i who pass from month $j-1$ to month j

$X_{i,j-1}$ = number of students of class i in month $j-1$.

For example, we would compute $CR_{1991,1,2}$ as $\frac{X_{1991,1,2}}{X_{1991,1}}$, which is equal to $\frac{135}{149} = 0.91$ (after rounding to two decimal places).

Now, suppose we want $CR_{1991,2,3}$, we would have $CR_{1991,2,3} = \frac{X_{1991,2,3}}{X_{1991,2}}$, which gives $CR_{1991,2,3} = \frac{117}{135} = 0.87$ (after rounding to two decimal places).

The rest of the continuation rate computations for each class i in each month j are similar.

b. Students Who Continue in the NS

One goal of the research is to predict the numbers of students of each class i in each month j who continue in the NS. In order to predict the "missing" numbers of Appendix A, the known numbers of each class i in each month j were used. A weighted average for obtaining a continuation rate estimator for the same reasons as before was used.

We compute weighted average continuation rates thus:

$$WAvCR_{i,j-1,j} = \frac{\sum X_{i,j-1,j}}{\sum X_{i,j-1}} \text{, where} \tag{3.5}$$

$WAvCR_{i,j-1,j}$ = fraction of students who passes from month $j-1$ to month j

$\sum X_{i,j-1,j}$ = number of students of classes i who pass from month $j-1$ to month j

$\sum X_{i,j-1}$ = number of students of classes i in month $j-1$.

In this particular case, each $X_{i,j-1,j}$ and $X_{i,j-1}$ value by itself represents its relative importance in the computation of weighted average.

To predict the continuation number of students of class 1998 in month 53, $X_{1998,53}$, we would have the next expression:

$$WAvCR_{i,52,53} = \frac{\sum X_{i,52,53}}{\sum X_{i,52}},$$

for i = 1991, 1992, 1993, 1994, 1995, 1996, 1997.

The summation symbol $\sum$ is used without designating its index i or the values for the index. We mean by this that the summation is for all the values of $X_{i,52,53}$ in the numerator and $X_{i,52}$ in the denominator.

If the values are substituted, from the table in Appendix A, each $X_{i,52,53}$ and each $X_{i,52}$ in the above expression would read:

$$WAvCR_{i,52,53} = \frac{50+61+59+56+61+76+78}{50+61+59+56+61+76+78} = 1.0$$

By using $WAvCR_{i,52,53}$ we can predict $X_{1998,53}$ as follows:

$$X_{1998,53} = X_{1998,52} * WAvCR_{i,52,53} = 49*1.0 = 49$$

To predict $X_{2001,17}$ the following is used:

$$WAvCR_{i,16,17} = \frac{\sum X_{i,16,17}}{\sum X_{i,16}},$$

for i = 1991, 1992, 1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000.

After substituting the equation reads:

$$WAvCR_{i,16,17} = \frac{\sum X_{i,16,17}}{\sum X_{i,16}} = \frac{68+71+86+72+97+121+116+76+91+134}{70+71+87+74+97+121+124+82+118+142} = 0.95$$

Having $WAvCR_{i,16,17} = 0.95$ (rounding to two decimal places), and $X_{2001,16}$ = 147, then

$X_{2001,17} = X_{2001,16} * WAvCR_{i,16,17} = 147 * 0.95 = 139$ (rounding to the closest integer)

The remaining "missing" numbers would be estimated in a similar way. By using Excel, and rounding each $WAvCR_{i,j-1,j}$ value to two decimal places and each $X_{i,j}$ value to the closest integer, a table was built (Appendix D). The predicted numbers of students of classes 1998 through 2002 who continued in the NS appear in the shadowed area of the table. The WAv column shows each of the $WAvCR_{i,j-1,j}$ estimator values.

5. The Naval School Probabilistic Transition Matrix (NSTPM)

The first goal of this thesis is by means of a probabilistic transition matrix to predict the number of officers who will graduate, as a function of the entering numbers, from the Naval School. To build the Naval School Probabilistic Transition Matrix (NSTPM) a weighted average continuation rate table was developed (Wav) in Appendix E. This table represents the fractions of students who pass from month $j-1$ to month j. These fractions are considered good estimators of the probabilities of a student passing from month $j-1$ to month j.

Another methodology for this flow of personnel month by month would be to consider each month as a state from where students are to move to either a new state or leave the NS. This flow of personnel transitions would move from one state to another, increasing one step at a time. In other words, if a student is in state 5, month 5, there are just two options for him; either to pass to state 6, month 6, or to leave the system by either attrition, desertion or death. There is neither a way of coming back to state 4, month 4, nor to remain in the same state. Personnel either leave the system or are promoted but are never demoted.

For example, the estimator for the probability of a student going from state $j-1$ to state j is $\hat{p}_{j-1,j}$, and the estimator for the probability of leaving the NS is $\hat{q}_{j-1,out}$, for all the values of j. It is clear that $\hat{p}_{j-1,j}$ + $\hat{q}_{j-1,out}$ = 1. This thesis considers the state "out" as an end state from where a student cannot get back in to the system.

The next equations, which are modifications of 3.5, represent these estimated probabilities.

$$\hat{p}_{j-1,j} = \frac{\sum X_{i,j-1,j}}{\sum X_{i,j-1}}, \text{ and} \tag{3.5a}$$

$$\hat{q}_{j-1,out} = \frac{\sum Y_{i,j-1,out}}{\sum X_{i,j-1}}, \text{ where} \tag{3.5b}$$

$\hat{p}_{j-1,j}$ = probability of a student of passing from month $j-1$ to month j

$\hat{q}_{j-1,out}$ = probability of a student of leaving the system in month $j-1$

$\sum X_{i,j-1,j}$ = number of students of classes i who pass from month $j-1$ to month j

$\sum Y_{i,j-1,out}$ = number of students of classes i who leave the system in month $j-1$

$\sum X_{i,j-1}$ = number of students of classes i in month $j-1$.

After these definitions it can be said that the second number of the Wav column of Appendix E represents the estimated probability of a student passing from state 1 (month 1) to state 2 (month 2), which is $\hat{p}_{1,2} = 0.88$. The rest of the Wav values, $\hat{p}_{j-1,j}$ values, have the same meaning; each value represents the probability of a student of passing to the next month. Of course $\hat{q}_{j-1,out} = 1 - \hat{p}_{j-1,j}$ is the probability of leaving the system.

If the Wav values in the matrix (matrix P of transition probabilities) are 61 rows by 61 columns, where each row represents the $j-1$ states and each columns the j states (for j (month)= 2, 3… 60), plus the end state "out", they would represent the NSTPM as shown in Appendix E. Rows 60 and 61 deserve an additional explanation. Students passing from state 60 to state "out" are in fact graduating with probability 1 and students being in state "out" remain in this state also with probability 1.

6. The Stochastic Process and Markov Chains

Ross [Ref 6: pp. 79, 80, 163-172] defines a stochastic process as follow:

> A stochastic process $\{X(t), t \in T\}$ is a collection of random variables. That is, for each $t \in T, X(t)$ is a random variable. The index t is often interpreted as time and, as result, we refer to $X(t)$ as the state of the process at time t.

In this case, $X(t)$ would be equal to $X_{i,j}$, the number of students of class i in months j.

Ross calls the set T the index set of the process. In this model, $j \in J$ equals $t \in T$. Since T is countable, as is J which extends from month 1 through month 60, the stochastic process is said to be a discrete-time process.

Moreover, Ross says that

> The state space of a stochastic process is defined as the set of all possible values that the random variables $X(t)$ [in our model, $X_{i,j-1,j}$ and $X_{i,j-1}$] can assume. Thus, a stochastic process is a family of random variables that describes the evolution through time of some (physical) process [in our model, the survival and continuation behavior of students in the NS represent such physical processes].

Ross considers

> [a] stochastic process $\{X_n, n = 1, 2, ...\}$ that takes on a finite or countable number of possible values. Unless otherwise mentioned, this set of possible values of the process will be denoted by the set of nonnegative integers $\{0,1,2,...\}$. If $X_n = i$, then the process is said to be in state i at time n. We suppose that whenever the process is in state i, there is a fixed probability P_{ij} that it will next be in state j. That is we suppose that
>
> $$P\{X_{n+1} = j / X_n = i, X_{n-1} = i-1, ..., X_1 = i_i, X_0 = i_0\} = P_{ij}$$

for all states $i_o, i_1, ..., i_{n-1}, i, j$ and all $n \geq 0$. Such a stochastic process is known as a Markov chain.

Ross interprets the above equation

[a]s stating that, for a Markov chain, the conditional distribution of any future state X_{n+1} given the past states $X_0, X_1, ..., X_{n-1}$ and the present state X_n, is independent of the past states and depends only on the present state. The value P_{ij} represents the probability that the process will, when in state i, next make a transition into state j. Since probabilities are nonnegative and since the process must make a transition into some state we have that

$$P_{ij} \geq 0 \qquad i, j \geq 0 \qquad \sum_{j=0}^{\infty} Pij = 1 \qquad i = 0, 1, ...$$

where P denotes the matrix of one-step transition probabilities P_{ij}.

$$P = \begin{pmatrix} P_{00} & P_{01} & P_{02} & \cdots \\ P_{10} & P_{11} & \cdots & \cdots \\ \vdots & \vdots & \vdots & \vdots \\ P_{i0} & P_{i1} & P_{12} & \cdots \\ \vdots & \vdots & \vdots & \vdots \end{pmatrix}$$

According to Ross, the NSTPM can defined as a matrix of one-step transition probabilities where

$$P_{ij} = p_{j-1,j}, \quad 1 - P_{ij} = q_{j-1,out}, \qquad i = j-1, \qquad \text{and } j = j, \qquad \text{for } j = 2, 3, ..., 60.$$

Then the NSTPM would be represented as follows:

$$NSTPM = \begin{pmatrix} 0 & p_{1,2} & 0 & \cdots & \cdots & \cdots & q_{1,out} \\ 0 & 0 & p_{2,3} & 0 & \cdots & \cdots & q_{2,out} \\ 0 & 0 & 0 & \cdots & \cdots & \cdots & \cdots \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ 0 & 0 & \cdots & \cdots & 0 & p_{59,60} & q_{59,out} \\ 0 & 0 & \cdots & \cdots & \cdots & \cdots & q_{60,out} \\ 0 & \cdots & \cdots & \cdots & \cdots & \cdots & q_{out,out} \end{pmatrix}$$

Each state of the NSTPM from state 1 through state 60 will be visited no more than once. These states can be defined as transient states, since each of them is visited a finite number of times. In other words, once an individual leaves a state he cannot come back. We also say that the Markov property holds.

The "out" state, which by Ross's definition is an absorbing state, is the only recurrent state in this finite-state Markov chain.

B. NAVAL SCHOOL GRADUATED OFFICERS TRANSITION PROBABILITIES MATRIX (NSGOTPM)

Before describing the Naval School Graduated Officers (NSGO) data it is necessary to highlight the following. The Mexican Navy promotes NSGO personnel on November 20th of each year. The new rank is officially adopted as soon as personnel in charge of this task have official written confirmation. For purposes of this research November 20th is considered the end of a promotional year, and November 21st the beginning of a promotional year.

On the other hand, personnel can leave the system any time during a promotional year. For purposes of uniformity we consider all separations occurring during a promotional year as happening on November 20th. For example, if a NSGO leaves the MN during 1985 he will be considered as leaving the system on November 20th, 1985, and he will not appear in the next promotional year beginning on November 21st, 1985 (which is the 1986 promotional year).

Since no Mexican Navy Law or Regulation considers a demotion as a possible event, an NSGO has the following alternatives while staying in the MN: to be promoted and make a transition to the next rank; not to be promoted and make a transition to the next promotional year thus increasing seniority by one year; or to leave the system for whatever reason.

1. The Description of the Data

The data for Naval School Graduated Officers (NSGO) was obtained from the General Director Personnel Control, Systematized Information Department in the Mexican Navy Headquarters, in Mexico City. The data contains the information on all the NSGO personnel from 1980 through November 20, 2002. This information reflects the personnel who are on active duty and those who separated from the MN during this period. A sample of the personnel on active duty, and a sample of the personnel who left the system is shown in Appendix G. The “Key Number” column contains an alphanumeric character that identifies each person (similar to SSN). For example, the “Key Number” VADF6011167G2 has the following meaning: VADF are the last and first name initial letters; 601116 are the year, month, and day of birth; finally, 7G2 is an indicator which prevents having two or more people with a same “Key Number”.

Table 3 supplements the information showed in the two samples appearing in Appendix F.

Situation / Rank Number	**Situation / Rank**
0	Out of system
11	Student
10	Midshipman
9	Ensign
8	Lieutenant Junior Grade
7	Lieutenant
6	Lieutenant Commander
5	Commander
4	Captain
3	Rear Admiral
2	Vice Admiral
1	Admiral

Table 3. Administrative situation of the NSGO personnel.

Since this research focuses on promotion-leave behavior of a NSGO after becoming an Ensign we will not consider the information appearing before this event occurs.

For example the "Key Number" person BOSD500806V57 (Appendix F; Active duty sample; second from the top) was Lieutenant Junior Grade on November 21, 1980 (and that day began his 1981 promotional year); on November 20, 1981 he was promoted to Lieutenant (and began his 1982 promotional year the next day); in 1985 he was promoted to Lieutenant Commander; in 1990 to Commander; in 1995 to Captain; in 2000 to Rear Admiral; by November 20, 2002 he was still Rear Admiral.

Another example is the "Key Number" person MUSM710528UF0 (Appendix F; Out of the system sample; eighth from the top). He was Ensign on November 21, 1994 (and it begun his 1995 promotional year), and by November 21, 1995 (his 1996 promotional year) he had left the Mexican Navy.

2. The Distribution of the NSGO Personnel

The distribution of the NSGO personnel by rank and by promotional year from 1986 through 2002 (this distribution represents the personnel we had on November 20 of each year from 1985 through 2001 who was about to start their next promotional year, 1986 through 2002) is listed in Appendix G. It seems that by showing the NSGO distribution from 1986 through November 2002 we are ignoring the data before 1986. But this is not the case. The following table helps to explain and clarify this point.

According to Appendix G on November 20, 1985 (it appears as 1986 in the top of the column because it is the 1986 promotional year) there were 70 Ensigns in their first year in the same rank, 45 in their second year, 67 in their third year, 28 in their fourth year, 16 in their fifth year, and 1 in their sixth or more year. We can apply this approach for describing each of the rank-seniority distributions. These particular distributions take in consideration the information from 1980 through 1985.

RANK IDENTIFICATOR	EQUIVALENT TO
9*1	Ensign during the first year in the same rank
9*2	Ensign during the second year in the same rank
9*3	Ensign during the third year in the same rank
9*4	Ensign during the fourth year in the same rank
9*5	Ensign during the fifth year in the same rank
9*6+	Ensign during the sixth (or more) year in the same rank
⋮	⋮
1*1	Admiral during the first year in the same rank
1*2	Admiral during the second year in the same rank
1*3	Admiral during the third year in the same rank
1*4	Admiral during the fourth year in the same rank
1*5	Admiral during the fifth year in the same rank
1*6+	Admiral during the sixth (or more) year in the same rank

Table 4. Rank seniority of the NSGO personnel.

3. The Distribution of the NSGO Promoted

The distribution of the NSGO personnel promoted on November 21 of each year from 1986 through 2002, where years 1986 through 2002 represent their promotional years, appears in Appendix H. In others words, these people were promoted on November 20 of each year from 1985 through 2001. These personnel made a transition to another rank.

4. The Distribution of the NSGO Not Promoted

The distribution of the NSGO personnel not promoted on November 21 of each year from 1986 through 2002, where years 1986 through 2002 represent their promotional years, appears in Appendix I. These personnel made a transition, in the same rank, to the next promotional year, and increased their seniority by one year.

5. The Distribution of the NSGO Who Left the MN

The distribution of the NSGO personnel, who had left the MN by November 21 of each year from 1986 through 2002, where years 1986 through 2002 represent their promotional years, appears Appendix J. These personnel made a final transition from active duty to the absorbing state "out" of the system.

6. The Naval School Graduated Officers Transition Probabilities Matrix (NSGOTPM)

a. *The Notation*

Defining the following indices:

r = rank (r = 9, 8, 7, 6, 5, 4, 3, 2, 1)

s = seniority Years (s = 1, 2, 3, 4, 5, 6+)

y = promotional Year (y = 1986, 1987,…, 2002)

and the nonnegative integer random variables:

$Z_{r,y}$ = number of NSGO of rank r in promotional year y

$X_{r.s,r.s+1,y}$ = number of NSGO of rank r who pass from seniority s to seniority $s+1$ in promotional year y

$W_{r.s,out,y}$ = number of NSGO of rank r with seniority s who leave the MN in promotional year y

$X_{r.s,r-1*1,y}$ = number of NSGO of rank r with seniority s who are promoted to rank $r-1$, and start their first promotional year in this new rank, in promotional year y

then, we have the following equilibrium equation:

$$Z_{r,y} = X_{r.s,r-1*1,y} + X_{r.s,r.s+1,y} + W_{r.s,out,y}. \tag{3.6}$$

This equation defines the way a stock of NSGO personnel ($Z_{r,y}$) is distributed into the three alternatives a NSGO has: Being promoted to seniority *1 of rank $r-1$ ($X_{r.s,r-1*1,y}$), not being promoted ($X_{r.s,r.s+1,y}$), and leaving the system ($W_{r.s,out,y}$).

b. The Probability Computations

D.J. Bartholowen, A.F. Forbes, and S.I. McClean [Ref. 7: pp. 112, 113] say that:

> If the Markov assumptions hold, it is easy to obtain point estimates of the transition probabilities from historical data by the method of maximum likelihood. For doing this we need complete stock and flow data. If $n_{ij}(T)$ is the observed number in i at T who are in j at $T+1$, and if $n_i(T)$ is the stock at the beginning of this interval, then the estimate of p_{ij} is
>
> $$\hat{p}_{ij} = \frac{n_{ij}(T)}{n_i(T)} \text{ for } i, j = 1, 2, 3, \ldots, k .$$
>
> If stock and flow are available over several time intervals for which the rates can be assumed to be the same then
>
> $$\hat{p}_{ij} = \frac{\sum_T n_{ij}(T)}{\sum_T n_i(T)} \text{ for } i, j = 1, 2, 3, \ldots, k .$$

D.J. Bartholowen, A.F. Forbes, and S.I. McClean [Ref. 7: pp. 97] define the Markov assumptions as follow:

(1) individuals move independently,

(2) and with identical probabilities which do not vary over time.

Since the population of the model by grade is homogeneous, p_{ij} represents the probability of each NSGO in rank i moving, independently of any other NSGO, to rank j after one promotional year.

By using 3.6 and the above, we can compute the fraction of NSGO personnel promoted, not promoted, and who left the system. For obtaining this probabilistic distribution, we use weighted averages as follows:

$$\hat{p}_{r.s,r-1*1} = \frac{\sum_{y=1986}^{2002} X_{r.s,r-1*1,y}}{\sum_{y=1986}^{2002} Z_{r,y}}$$, where $\hat{p}_{r.s,r-1*1}$ represents the probability of a NSGO being promoted from rank r, with seniority s, to rank $r-1$, and starting his next promotional year in this new rank, which corresponds to the first year in this grade.

$$\hat{p}_{r.s,r.s+1} = \frac{\sum_{y=1986}^{2002} X_{r.s.r.s+1,y}}{\sum_{y=1986}^{2002} Z_{r,y}}$$, where $\hat{p}_{r.s,r.s+1}$ represents the probability of a NSGO of rank r, with seniority s, not being promoted and passing to seniority $s+1$.

$$\hat{q}_{r.s,out} = \frac{\sum_{y=1986}^{2002} X_{r.s,out,y}}{\sum_{y=1986}^{2002} Z_{r,y}}$$, where $\hat{q}_{r.s,out}$ represents the probability of a NSGO of rank r, with seniority s, leaving the MN.

It is clear that

$$\hat{p}_{r.s,r-1*1} + \hat{p}_{r.s,r.s+1} + \hat{q}_{r.s,out} = 1.$$

In order to speed the computations we used Excel, rounding to two decimal places. Appendix K shows the probabilities of a NSGO being promoted, not being promoted, and leaving the Mexican Navy.

c. The Naval School Graduated Officers Transition Probabilities Matrix NSGOTPM

If these probabilities are arranged in a matrix (matrix P of transition probabilities) of 55 rows by 55 columns, where the first 54 rows represent the $r.s$ states and the row 55 the state "out", the first 54 columns the $r.s+1$ and $r-1*1$ states and the column 55 the end state "out" (the absorbing state), we have built the NSGOTPM. Our NSGOTPM is represented as follows:

$$
\text{NSGOTPM}=\begin{bmatrix}
0 & p_{9*1,9*2} & 0 & 0 & 0 & 0 & p_{9*1,8*1} & \dots & 0 & 0 & 0 & \dots & q_{9*1,out} \\
0 & 0 & p_{9*2,9*3} & 0 & 0 & 0 & p_{9*2,8*1} & \dots & 0 & 0 & 0 & \dots & q_{9*2,out} \\
\vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \dots & \vdots & \vdots & \vdots & \dots & \vdots \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & \dots & 0 & p_{1*1,1*2} & 0 & \dots & q_{1*1,out} \\
\vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \dots & \vdots & \vdots & \vdots & \dots & \vdots \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & \dots & 0 & 0 & 0 & \dots & q_{out,out}
\end{bmatrix}
$$

Appendix L shows the NSGOTPM.

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IV. MODEL DESCRIPTION

A. GRADUATING FROM THE NAVAL SCHOOL (NS)

1. The Expected Number of Graduating Students

For predicting the number of people graduating from the NS we use the Markov model applied to length-of-service distribution [Ref. 7; pp. 106]. About this model, the authors say:

> First we consider a population in which people are classified according to length of service. Suppose also that each length-of-service category is the same width as the discrete-time interval of the model [one month for our model]. Under these circumstances there are only two possible transitions open for an individual: either he must leave or increase his length of service by one time unit. This means that the $k \times (k+1)$ array of transition probabilities will have the following form:
>
> $$\begin{bmatrix} 0 & p_{12} & 0 & \cdots & 0 & w_1 \\ 0 & 0 & p_{23} & \cdots & 0 & w_2 \\ \vdots & \vdots & \vdots & & \vdots & \vdots \\ 0 & 0 & 0 & \cdots & p_{k-1,k} & w_{k-1} \\ 0 & 0 & 0 & \cdots & 0 & 1 \end{bmatrix}$$
>
> The $w's$ are the length-of-service specific wastage [attritions] rates and, of course,
>
> $p_{i,i+1} = 1 - w_i \quad (i = 1, 2, \ldots, k-1)$
>
> k is the maximum length of service after which everyone must leave.

The above array of probabilities is identical to the NSTPM described in III.6. The $w's$, the length-of-service wastages rates, are equal to the q estimators we defined for the NSTPM. The index k above is equal to j in our model.

When using the Markov model applied to length-of-service distribution, the authors add:

> If the length-of-service specific wastage rates can be assumed constant through time then the Markov model can be used to project the length-of-service structure.

This last consideration is the second Markov assumption which states that the transition probabilities do not change over time. By observing this assumption, the Markov model can be used to project the Mexican Naval School length-of-service structure as follows:

$$\overrightarrow{X_{j-1,j}} = NSTPM^T * \overrightarrow{X_{j-1}} \text{, where} \tag{4.1}$$

$\overrightarrow{X_{j-1,j}}$ = vector that represents the number of students who increase their length-of-service by one month

$NSTPM^T$ = the matrix of transition probabilities transposed

$\overrightarrow{X_{j-1}}$ = vector that represents the number of students who have length-of-service equal to $j-1$ months,

for each $j = 2, 3, \ldots, 59, 60$ months.

For example, the estimated number of students graduating classes 1998 and 2003 would be:

$\overrightarrow{X_{j-1}} = \overrightarrow{X_1} = (158, 0, ..., 0, 0)^T$ (for class 1998),

$\overrightarrow{X_{j-1}} = \overrightarrow{X_1} = (231, 0, ..., 0, 0)^T$ (for class 2003),

$\overrightarrow{X_{j-1,j}} = (X_{1,2}, X_{2,3}, \ldots, X_{58,59}, X_{59,60})^T$ (for both classes),

and the same $NSTPM^T$.

The length-of-service distribution for classes 1998 and 2003 is shown in Appendix M. Excel rounding to the closest integer was used to compute this distribution. The top two shaded cells represent the entering numbers of students and the bottom two shaded cells are the numbers of students that we predicted to be graduated from the Mexican Naval School after staying for 60 months.

Each table in Appendix M “Entering Number” column is the entering student vector of each class. Since this research assumes that only in the first period, $j-1=1$, a student can join the NS, the rest of the vector's values are zeros; thus, a class cannot be increased in number after period one. On the other hand, the "Continuing Number" columns, of the same Appendix M, show the estimated numbers of students that remain in the NS month by month until they graduate in month 60.

2. The Recruiting Vector for Classes 1999-2002

After graduating from the NS a student spends a year as Midshipman then he is promoted to Ensign[2]. There are two length-of-service Subsystems to be considered: the Student-Midshipman length-of-service as Subsystem A and the Ensign-Admiral length-of-service as Subsystem B. Subsystem A shows all personnel that transition to the first category of the grade Subsystem B Markov chain or that leave the system. This figure is referred as the "recruiting vector" $\vec{R}$ of personnel passing from Subsystem A to Subsystem B. Such as vector is described as:

$$\vec{R} = \left(X_{9*1}, X_{9*2}, \ldots, X_{5*1}, X_{5*2}, \ldots, X_{1*5}, X_{1*6+} \right)^T$$

Since personnel coming from Subsystem A can join Subsystem B only as Ensigns during their first year of seniority, it is clear that:

$$X_{9*2}, \ldots, X_{5*1}, X_{5*2}, \ldots, X_{1*5}, X_{1*6+} = 0$$

Hence, this vector is reduced to:

$$\vec{R} = \left(X_{9*1}, 0, \ldots, 0, 0, \ldots, 0, 0 \right)^T$$

Finally, the "recruiting vector" is represented as

$$\vec{R} = \lambda * \vec{r} \text{, where} \tag{4.2}$$

λ is a scalar defining the entering number of students observed in 1999 through 2002, and $\vec{r}$ is a vector whose first element represents the expected fraction of students who would graduate from the NS and would join Subsystem B one year later. This element is also interpreted as the probability of a student graduating from the NS.

---

[2] This research assumes that all of the students graduating from the NS will spend exactly one year as Midshipmen. After this period, all of them will be promoted to Ensign.

In part III.A.3 (see also Appendix C) it was shown that the expected fraction of the entering number of students graduating from the NS is 0.31 (rounded to two decimal places). Thus, the vector of probabilities $\vec{r}$ has the following shape:

$$\vec{r} = (0.31, 0, 0, \ldots, 0, 0)^T$$

By using this vector and the entering number of students observed from 1999 to 2002 (λ), we can predict the number of personnel joining Subsystem B in 2005 through 2008. But, this prediction can be done if and only if these personnel are to stay as students in the Mexican Naval School for no more than five years, and as Midshipmen for no more than one year.

3. The Vector Factor for Classes 1997 and 1998

Since equation 4.2 only predicts the personnel of classes 1998 through 2002 passing from Subsystem A to Subsystem B, we define the vector Factor for classes 1997 and 1998. The vector Factor represents the estimated number of Midshipmen joining, as Ensigns, Subsystem B in years 2003 and 2004. This vector is decomposed as follows:

$$\overrightarrow{Factor} = \gamma * \vec{g} \text{, where} \tag{4.3}$$

γ is a scalar having the value of 72 for class 1997 and 48 for class 1998; 72 are the Midshipmen we already had in stock in November 2002, whereas 48 are the expected students to be graduated from the NS in 2003. Finally, the vector $\vec{g}$ has this form:

$$\vec{g} = (1, 0, 0, \ldots, 0, 0)^T .$$

By writing (4.2) and (4.3) together, we have:

$$\vec{R} + \overrightarrow{Factor} = \lambda * \vec{r} + \gamma * \vec{g} \tag{4.4}$$

Equation 4.4 defines the number of personnel that pass from Subsystem A to Subsystem B the next six years (2003-2008).

4. The Predicted Number of Personnel Joining the NS in 2003 Through 2006

The goal of this research to predict the NSGO in the short and long term requires an analysis of the next ten years (from 2003 through 2012). By using 4.4, personnel passing from Subsystem A to Subsystem B, we could only predict the NSGO personnel distribution from 2003 to 2008. Thus, an estimated number of personnel entering to the Naval School in 2003 through 2006 for predicting this distribution from 2009 to 2012 would be required.

To obtain the estimated entering numbers in 2003 through 2006 this research considered the known entering numbers from 1991 to 2002 as "time series data." After plotting the data seasonality or a regular, repeating pattern every four years was observed. The following graph shows that a low entering number value, compared with the previous values, is observed in 1994, 1998, and 2002.

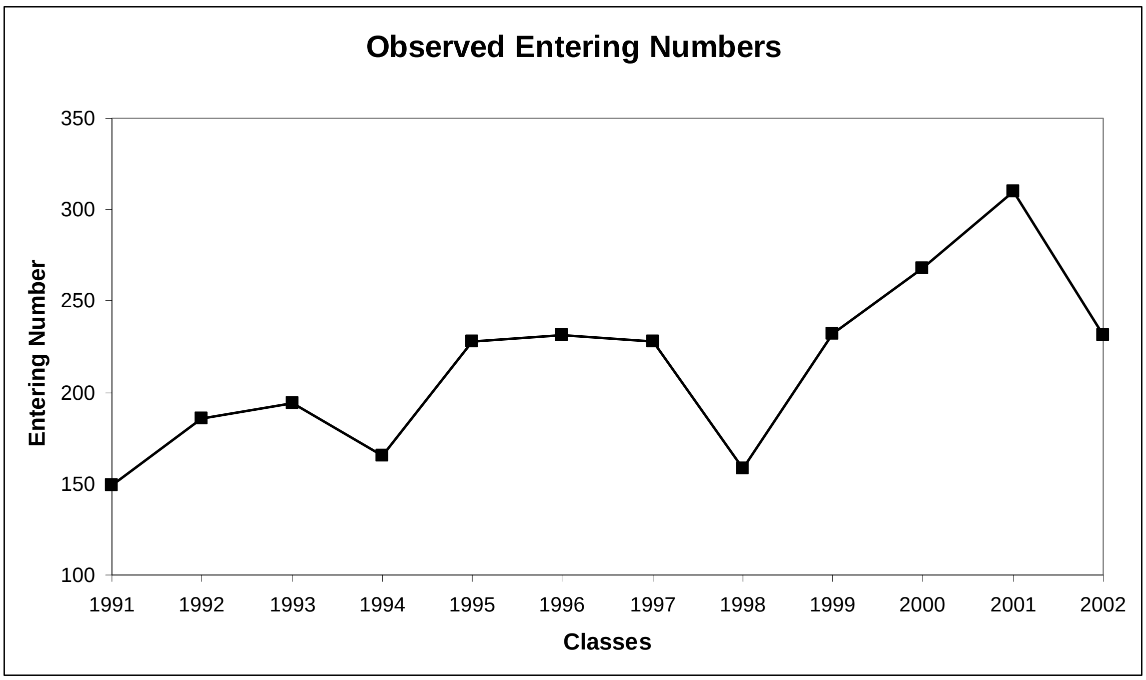

Figure 6. Entering students to the NS in 1991 through 2002

About time series data showing seasonality, Cliff T. Ragsdale [Ref. 9; pp. 501-509] says that:

Two different types of seasonal effects are common in time series data: additive effects and multiplicative effects. Additive seasonal effects tend to be on the same order of magnitude each time a given season is encountered. Multiplicative seasonal effects tend to have an increasing effect each time a given season is encountered. The following model is useful for modeling stationary time series data with additive seasonal effect:

$$\hat{Y} = E_t + S_{t+n-p}$$

where

$$E_t = \alpha(Y_t - S_{t-p}) + (1-\alpha)\mathrm{E}_{t-1}$$

$$S_t = \beta(Y_t - E_t) + (1-\beta)S_{t-p}$$

$$0 \le \alpha \le 1 \quad \textit{and} \quad 0 \le \beta \le 1$$

In this model, E_t represents the expected level of the time series in period t and S_t represents the seasonal factor for period t. The constant p represents the number of seasonal periods in the data. [The weights parameters α and β can assume any value between 1 and 0.]

An additive model was used instead of the multiplicative model because the first technique seems to fit the original time series data better. Appendix N shows the estimated entering numbers after using the additive seasonal model given by Ragsdale. The values obtained except those for alpha and beta are rounded to two decimal places, and the estimated entering numbers were later rounded to the closest integer. The values for alpha and beta, which minimize the Mean Square Error[3] (MSE) value, were obtained using the "solver tool" in Excel.

By putting together IV.A.2, 3, and 4, we finally have the estimated personnel who will pass from Subsystem A to Subsystem B during the next 10 years. The following table summarizes the information obtained above.

[3] The MSE measures how apart the observed entering numbers in 1995 through 2002 are from those predicted for the same period after using the additive seasonal model.

Class	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Promotional Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
λ			232	268	310	231	252	281	293	232
γ	72	48								
	GRADUATED		OBSERVED					PREDICTED BY USING ADDITIVE SEASONAL EFFECT		

Table 5. Personnel passing from Subsystem A to Subsystem B before applying $\vec{R} = \lambda * \vec{r}$ and $\overrightarrow{Factor} = \gamma * \vec{g}$.

According to Table 5, it is clear that $\vec{R} = \lambda * \vec{r}$ is equal to zero in years 2003 and 2004; whereas $\overrightarrow{Factor} = \gamma * \vec{g}$ is equal to zero in 2005 through 2012.

The vector $\overrightarrow{Factor} = \gamma * \vec{g}$ values deserve an additional explanation. For year 2003 we use the value 72 instead of 78 (appearing in Appendix A for class 1997) because 72 is the number of Midshipmen we have in stock in November 2002 (see further explanation in IV.B.1.a, and Appendix O). And, based on Appendix D, for year 2004 we estimated that 48 students would graduate in 2003.

B. ESTIMATING THE DISTRIBUTION OF THE NAVAL SCHOOL GRADUATED OFFICERS (NSGO) BY USING THE NSGOTPM, THE INITIAL STOCK VECTOR, THE VECTOR RECRUITS, AND THE VECTOR FACTOR

After obtaining Table 5, we can now estimate the NSGO personnel distribution for the next ten years by means of using the following equation:

$$\overrightarrow{S_{NSGO}(t+1)} = NSGOTPM^T * \overrightarrow{S_{NSGO}(t)} + \vec{R} + \overrightarrow{Factor} = NSGOTPM^T * \overrightarrow{S_{NSGO}(t)} + \lambda * \vec{r} + \gamma * \vec{g} \qquad (4.5)$$

where

$\overrightarrow{S_{NSGO}(t+1)} =$ is the stock vector of NSGO personnel for the next period

$\overrightarrow{S_{NSGO}(t)} =$ is the stock vector of NSGO personnel in the present period, and the rest equation 4.5 elements are as defined in part IV.C.

The NSGO data shows that the initial stock, $\overrightarrow{S_{NSGO}(t)}$, of NSGO personnel in November 21, 2002 was as it appears in Appendix O (shaded column). Appendix O shows the estimated distribution, $\overrightarrow{S_{NSGO}(t+1)}$, of NSGO personnel from 2003 through 2012.

C. COMPARING THE ESTIMATED NSGO DISTRIBUTION WITH THE TARGETS DISTRIBUTION (NGSO PERSONNEL REQUIRED)

In the introductory part of this research the Mexican Navy S-1 stated that because of inefficient manpower planning there is a large deficit of NSGO inventory in the Ensign through Lieutenant Grades, and an excess of these personnel inventory in the higher grades. Next, a measurement of how far the estimated distribution of NSGO personnel, computed in IV.B, is from the target distribution (NSGO personnel needed in each rank). The target distribution that existed by November 2002 appears in table 6 and accompanies the expected numbers of NSGO that will survive over the next ten years. This research assumes that the target distribution will remain constant during this period, and that the numbers of NSGO, both estimated and required, are considered on November 21st which is the beginning of each promotional year.

EXPECTED TO HAVE										
Grades \ Year	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
9	218	215	231	253	290	298	301	304	313	307
8	222	198	193	204	215	226	243	268	288	299
7	566	490	381	310	278	246	232	232	239	251
6	480	536	577	583	577	542	471	390	330	291
5	351	370	406	446	474	522	575	611	623	619
4	301	319	356	377	380	393	419	454	485	512
3	141	156	171	189	206	226	247	269	289	306
2	70	78	86	90	93	101	110	120	131	142
1	18	19	17	19	20	20	20	21	23	24
EXPECTED TO NEED										
Grades \ Year	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
9	662	662	662	662	662	662	662	662	662	662
8	745	745	745	745	745	745	745	745	745	745
7	677	677	677	677	677	677	677	677	677	677
6	378	378	378	378	378	378	378	378	378	378
5	334	334	334	334	334	334	334	334	334	334
4	206	206	206	206	206	206	206	206	206	206
3	85	85	85	85	85	85	85	85	85	85
2	33	33	33	33	33	33	33	33	33	33
1	10	10	10	10	10	10	10	10	10	10

Table 6. Unconstrained NSGO Inventory and Demand expected 2002-2012 (next ten years).

The upper part of Table 6 shows the NSGO personnel forecasted in each grade for the next ten years[4]. The lower table section depicts the numbers of NSGO personnel that will be needed during the same period[5]. A comparison of the two sections shows how big the gaps in each grade will be if the same promotional behavior is maintained as observed over the last 20 years in the Mexican Navy.

[4] This part of the table is a summarized form of Appendix's P table. For example, the forecasted number of Ensigns (the row for the grade indicator 9) for 2003 is the result of adding up the numbers we would have for 9*1 through 9*6+ in that year, which is equal to 218, after rounding to the closest integer. The same reasoning can be applied in each row and in each year to this table section. This approach is needed because the target number information obtained does not specify how many personnel in each rank are needed with a specific seniority.

[5] This research assumes these numbers to remain constant throughout this time.

D. OPTIMIZING THE NUMBER OF NSGO TO PROMOTE BY GRADE WHILE MAINTAINING THE NSGOTPM "OUT" STATE PROBABILITIES CONSTANT

By maintaining the same promotion policies observed the last 20 years it is highly improbable that the Mexican Navy will meet its NSGO personnel targets either in the short or in the long term. Action must be taken to reduce the estimated gaps in each grade predicted for the next ten years. This research considers that by changing some of the NSGOTPM probabilities, some of the gap between inventory and demand can be significantly reduced.

Bartolomew, Forbes, and McClean [Ref. 7; pp. 1-2] express the following about manpower planning:

> Manpower planning is often defined as the attempt to match the supply of people with the jobs available for them…. There are two features of most manpower planning problems, which render them suitable for statistical treatment. The first is the concern with aggregates. Manpower planning, unlike individual planning, is concerned with numbers, that is, with having the right numbers in the right places at the right time…. The second feature of manpower planning which calls for statistical expertise is the fact of uncertainty. This arises both from the uncertainty inherent in the social and economical environment in which the firm [organization] operates and from the unpredictability of human behavior. Any attempt to construct a theoretical base for manpower planning must therefore reckon with the element of uncertainty by introducing probability ideas.

Trying to match as closely as possible NSGO Personnel Inventory to NSGO Personnel Demand is one the goals of this thesis. To accomplish this, it was decided to partition the NSGOTPM into nine sub-matrices that describe the promotional behavior of each rank. Each of the nine sub-matrices appears in the shaded areas of Appendix's P matrix. The "out" state probabilities for each sub-matrix are also considered; they, however, remain constant through the computations. These "out" probabilities, as the others probabilities, come from historical data.

In addition to this, the values of the cells appearing out side of the shaded areas are neither altered during the computations. Next an optimization model is described for each grade, which aims to reduce the observed gaps.

1. Reducing Ensign Inventory Gaps

In an effort to reduce the observed differences between inventory and demand in this grade, a technique that uses a non-linear criterion for aggregating the error for observation i (each promotional year) is used. This non-linear criterion measures how far away the estimated value $\hat{Y}_i$ (estimated inventory) is from the actual value Y_i (estimated demand). This method is represented by:

Minimize

$$\sum_{i=2003}^{2012} \left(Y_i - \hat{Y}_i \right)^2 \quad for \quad i = 2003, \ldots, 2012,$$

by changing

$NSGOTPM_{9,8*1}$

given

$$\hat{Y}_i = \sum_{s=1}^{6} \overrightarrow{X_{j,s,i}} \qquad \begin{array}{l} for \quad s = 1,2,3,4,5,6+, \quad j = 9 \\ and \quad each \quad i \end{array}$$

$\overrightarrow{X_{j,s,i}} = NSGOTPM^{T}_{9,8*1} * \overrightarrow{S_9(2002)} + \lambda * \vec{r} + \gamma * \vec{g} \quad for \quad each \quad j, s, i$, where

$\hat{Y}_i =$ is the Ensign Personnel Inventory Estimated from 2003 to 2012

$\overrightarrow{X_{j,s,i}} =$ is the expected vector distribution of Ensign Personnel from 2003 to 2012

$Y_i =$ is the Ensign Personnel Demand Estimated from 2003 to 2012, which this research assumes to remain constant

$NSGOTPM^{T}_{9.8*1} =$ is the sub-matrix of transitions probabilities transposed for Ensign Personnel

$\overrightarrow{S_9(2002)} =$ is the initial stock vector of Ensign Personnel we had in 2002

$Subject \quad to : (NSGOTPM_{9,8*1} \quad probabilities)$

Constraint 1:

$0 \leq p_{9*1,9*2}, p_{9*1,out}, ..., p_{9*6+,out}, p_{8*1,out} \leq 1$ constraints assuring a transition either to a more senior state or to the "out" state (13 of them)

Constraint 2:

$p_{9*1,9*3}, p_{9*1,9*4}, ..., p_{9*3,9*6+}, p_{9*4,9*6+} = 0$ constraints not allowing transitions greater than one step (10 of them)

Constraint 3:

$p_{9*2,9*1}, p_{9*3,9*2}, ..., p_{9*6+,9*2}, p_{9*6+,9*1} = 0$ constraints assuring no decrease in seniority (15 of them)

Constraint 4:

$p_{9*1,8*1}, p_{9*2,8*1}, p_{9*3,8*1} = 0$ constraints assuring that personnel are not promoted with three or fewer years of seniority (3 of them)

Constraint 5:

$p_{9*4,8*1}, p_{9*5,8*1}, p_{9*6+,8*1} \geq p \ \ (p > 0)$ constraints assuring minimum promotion probabilities of personnel with at least four years of seniority (3 of them), where:

$p_{9*4,8*1} \geq 0.40$, $p_{9*5,8*1} \geq 0.35$, $p_{9*6+,8*1} \geq 0.10$

Constraint 6:

$p_{9*1,9*1}, p_{9*2,9*2}, ..., p_{9*5,9*5}, p_{8*1,8*1} = 0$ constraints not allowing personnel to remain in the same state the next promotional year (6 of them)

Constraint 7:

$p_{8*1,9*6+}, ..., p_{8*1,9*1} = 0$ constraints assuring that no personnel are demoted (6 of them)

Constraint 8:

$p_{out,9*1}, p_{out,9*2}, ..., p_{out,9*6+}, p_{out,8*1} = 0$ constraints not allowing personnel to come back from the "out" state to active duty (7 of them)

Constraint 9:

$p_{out,out} = 1$ constraint assuring to keep personnel in the "out" state

Constraint 10:

$$\left.\begin{array}{l} p_{9*1,9*1} + p_{9*1,9*2} + ... + p_{9*1,8*1}, p_{9*1,out} = 1 \\ \qquad\qquad \vdots \\ p_{out,9*1} + p_{out,9*2} + ... + p_{out,8*1}, p_{out,out} = 1 \end{array}\right.$$

constraints assuring row addition to one (8 of them)

Constraint 11:

$p_{9*1.out} = p_{9*1.out}, p_{9*2.out} = p_{9*2.out}, ..., p_{9*6+.out} = p_{9*6+.out}, p_{8*1.out} = p_{8*1.out}$ constraints keeping the "out" state probabilities[6] constant (7 of them)

Constraint 12:

$p_{i,j} \geq 0$ non-negativity constraint.

After applying the above model and using the "solver tool" in Excel for minimizing the objective non-linear function, the following table is obtained:

[6] These "out" state probabilities were first estimated from historical data then fixed to their estimated values by using this constraint.

From/To	9*1	9*2	9*3	9*4	9*5	9*6+	8*1	out
9*1		1.00						
9*2			0.99					0.01
9*3				0.99				0.01
9*4					0.58		0.40	0.02
9*5						0.56	0.35	0.09
9*6+						0.78	0.10	0.12
8*1								
out								1.00

Grade	S(2002)	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
9*1	58	72	48	72	83	96	72	78	87	91	72
9*2	56	58	72	48	72	83	96	71	78	87	91
9*3	50	56	57	71	48	71	82	95	71	77	86
9*4	18	50	55	57	71	47	71	82	95	71	77
9*5	0	11	29	32	33	41	28	41	48	55	41
9*6+	4	3	8	23	36	47	60	62	72	83	96
8*1	0	**8**	**24**	**33**	**36**	**44**	**38**	**44**	**53**	**62**	**56**

Grade	Estimated	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	sumxsy2=
$9\left(\hat{Y}_i\right)$	Have	249	270	303	343	386	408	430	450	464	463	
$9\left(Y_i\right)$	Need	662	662	662	662	662	662	662	662	662	662	873125.8

Table 7. Distribution of Ensign Inventory after using the “solver tool” in Excel.

Table 7 deserves the following explanation:

- The transition matrix shows the probabilities, rounded to two decimal places, which minimize the objective function.
- The minimized value for the objective function appears below the sumxsy2 column (sumxsy2 is the Excel function that computes the Error Sum of Squares).
- The middle section of Table 7 depicts the estimated distribution, rounded to the closest integer, for Ensign Personnel for the next ten years, given the initial stock vector $\overrightarrow{S_9(2002)}$.
- This section also shows the expected numbers of Ensign to promote during the mentioned period. These numbers appear in front of the 8*1 grade indicator, and represent the personnel who would join the next rank on the Markov chain. By multiplying each of these numbers, identified as the variable $promoted(8*1)$, by a vector of the form $next^T = (1,0,0,0,0,0)$, we add them to the first category of the Lieutenant Junior Grade Markov chain in state 8*1.
- Finally, the bottom section of table 7 compares the Expected Inventory against the Expected Demand of Ensign Personnel.

2. Reducing Lieutenant Junior Grade, Lieutenant, Lieutenant Commander, Commander, Captain, Rear Admiral, and Vice Admiral Inventory Gaps

The same model was used to reduce these inventory discrepancies with correspondent modifications required to accommodate each of the grades' transition probabilities matrices, initial stocks, and expected demands. Tables similar to table 7 were built, and each of them is explained similarly to this table. The probabilities that minimize the objective function (after using the "solver tool" and rounding to two decimal places) for each grade appear in Appendix Q. The distributions and the Expected Inventory (rounded to the closest integer) against the Expected Demand for each rank appear in Appendix R and Appendix S, respectively. The following equations, which are the major modification to the above model, compute the personnel distribution for each rank:

$\overrightarrow{X_{j,s,i}} = NSGOTPM_{8,7*1} * \overrightarrow{S_8(2002)} + promoted(8*1) * \overrightarrow{next}$ for each j,s,i; for Lieutenant Junior Grade Personnel, and Constraint 5 is changed to accommodate $p_{8*4,7*1} \geq 0.30, p_{8*5,7*1} \geq 0.20, p_{8*6+,7*1} \geq 0.10$

$\overrightarrow{X_{j,s,i}} = NSGOTPM^{T}_{7,6*1} * \overrightarrow{S_7(2002)} + promoted(7*1) * \overrightarrow{next}$ for each j,s,i; for Lieutenant Personnel, and Constraint 5 is changed to accommodate $p_{7*4,6*1} \geq 0.15, p_{7*5,6*1} \geq 0.10, p_{7*6+,6*1} \geq 0.05$

$\overrightarrow{X_{j,s,i}} = NSGOTPM^{T}_{6,5*1} * \overrightarrow{S_6(2002)} + promoted(6*1) * \overrightarrow{next}$ for each j,s,i; for Lieutenant Commander Personnel, and Constraint 5 is changed to accommodate $p_{6*4,5*1} \leq 0.15, p_{6*5,5*1} \leq 0.10, p_{6*6+,5*1} \leq 0.05$

$\overrightarrow{X_{j,s,i}} = NSGOTPM^{T}_{5,4*1} * \overrightarrow{S_5(2002)} + promoted(5*1) * \overrightarrow{next}$ for each j,s,i; for Commander Personnel, and Constraint 5 is changed to accommodate $p_{5*4,4*1} = 0, p_{5*5,4*1} \leq 0.15, p_{5*6+,4*1} \leq 0.05$.

$\overrightarrow{X_{j,s,i}} = NSGOTPM_{4,3*1}^{T} * \overrightarrow{S_4(2002)} + promoted(4*1)*\overrightarrow{next}$, for each j,s,i; for Captain Personnel, and <u>Constraint 5</u> is changed to accommodate $p_{4*4,3*1} = 0, p_{4*5,3*1} = 0, p_{4*6+,3*1} \leq 0.05$

$\overrightarrow{X_{j,s,i}} = NSGOTPM_{3,2*1}^{T} * \overrightarrow{S_3(2002)} + promoted(3*1)*\overrightarrow{next}$, for each j,s,i; for Rear Admiral Personnel, and <u>Constraint 5</u> is changed to accommodate $p_{3*4,2*1} = 0, p_{3*5,2*1} = 0, p_{3*6+,2*1} \leq 0.05$

$\overrightarrow{X_{j,s,i}} = NSGOTPM_{2,1*1}^{T} * \overrightarrow{S_2(2002)} + promoted(2*1)*\overrightarrow{next}$, for each j,s,i; for Vice Admiral Personnel, and <u>Constraint 5</u> is changed to accommodate $p_{2*4,1*1} = 0, p_{2*5,1*1} = 0, p_{2*6+,1*1} \leq 0.04$

3. Accommodating Each of the Nine Sub-Matrices Into the NSGOTPM

If we now accommodate the nine sub-matrices already obtained into the NSGOTPM and apply equation 4.5, which is

$\overrightarrow{S_{NSGO}(t+1)} = NSGOTPM^T * \overrightarrow{S_{NSGO}(t)} + \vec{R} + \overrightarrow{Factor} = NSGOTPM^T * \overrightarrow{S_{NSGO}(t)} + \lambda * \vec{r} + \gamma * \vec{g}$, we would obtain the same NSGO personnel distributions as obtained when applying the model described in IV.D.1, and 2. These distributions showing the Expected Inventory (rounded to the closest integer) against the Expected Demand for each rank also appear in Appendix S.

E. OPTIMIZING THE NUMBER OF NSGO TO PROMOTE BY GRADE WHILE VARYING THE NSGOTPM "OUT" STATE PROBABILITIES

The model described in IV.D.1, and 2 considers that the historical probabilities of leaving the Mexican Navy do not change at all. Now, changing some of the "out" state probabilities, while using the same 12 constraints, the model shows a different NSGOTPM, after accommodating each of the nine sub-matrices, and different personnel distributions. The resulting NSGOTPM and NSGO personnel distributions appear in Appendix T, Appendix U and Appendix V.

F. OPTIMIZING THE NUMBER OF NSGO TO PROMOTE BY RANK WHILE VARYING THE NSGOTPM “OUT” STATE PROBABILITIES AND THE PROBABILITY OF GRADUATING FROM THE NS

In chapter paragraphs IV.D and E an optimization of the NSGO inventory for the next ten years was based on the expected inventory demand for the same period. In both cases, constant “out” probabilities and changing “out” probabilities, we did not take in count the future performance of the NS school; we assumed that the probability of graduating from the NS would remain constant in 0.31 for the next ten years. However, we consider that the NS role must be taken in count during the NSGO personnel optimization process. A higher probability of graduating from the NS will reduce the gaps observed in the junior grades categories faster, whereas a lower probability will slow this process.

For trying to reduce the observed gaps in the NSGO inventory, we used a variation of the model presented in part IV.D and E. We use all 12 constraints but constraint 5. Instead of using constraint 5, we allow the model to find the probabilities that will minimize the objective function. These values will represent the probability of promoting an NSGO by rank with a seniority of at least tree years.

In addition to the above explained, we now use the complete NSGOTPM, instead of optimizing separately each of the nine sub-matrices, and equation 4.5 for minimizing the objective function. We also assign a weight to each grade to stress the importance of each rank during the optimization process. Next we show the model:

Minimize $\quad$ *for* $\quad i = 2003, \ldots, 2012$

$$\sum_{i=2003}^{2012} W_j \left(Y_{j,i} - \hat{Y}_{j,i} \right)^2 \qquad \textit{and} \quad \textit{each} \quad j$$

by changing

$NSGOTPM$ and $\vec{r}$

given

$W_j = 1 / Y_{j,i}$

$$\hat{Y}_{j,i} = \sum_{s=1}^{6} \overrightarrow{X_{j,s,i}} \qquad \begin{matrix} for & s = 1,2,3,4,5,6+ \\ and \quad each & j,i \end{matrix}$$

$$\overrightarrow{X_{j,s,i}} = NSGOTPM^{T} * \overrightarrow{S_{NSGO}(2002)} + \lambda * \vec{r} + \gamma * \vec{g} \qquad for \quad each \quad j,s,i$$, where

$W_j =$ is the weight assigned to each rank for each year according to the NSGO Personnel Demand Estimated from 2003 to 2012, which this research assumes to remain constant

$\hat{Y}_{j,i} =$ is the NSGO Personnel Inventory Estimated from 2003 to 2012 in each rank

$\overrightarrow{X_{j,s,i}} =$ is the expected vector distribution of NSGO Personnel from 2003 to 2012 in each rank

$Y_{j,i} =$ is the NSGO Personnel Demand Estimated from 2003 to 2012 in each rank

$NSGOTPM^{T} =$ is the matrix of transitions probabilities transposed

$\overrightarrow{S_{NSGO}(2002)} =$ is the initial stock vector by ranks of NSGO personnel we had in 2002

After applying the above model we obtain a new NSGOTPM and different personnel distributions. Also, the probability of graduating from the Naval School changes from 0.31 to 0.58. The resulting NSGOTPM and NSGO personnel distributions appear in Appendix W, Appendix X and Appendix Y.

V. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

The NSTPM and NSGOTPM models were used to predict future NSGO personnel inventory distributions while maintaining established promotion policies. However, the data showed large discrepancies between expected inventories and demands in the NSGO personnel structure.

This research established a model to minimize those expected gaps by changing some of the NSGOTPM probabilities. The result of this methodology resulted in two important perspectives. Firstly, the MN should increase the time a NSGO spends in the junior grades categories, Ensign through Lieutenant Commander, and decrease the number of personnel leaving the system in the same grades categories. Secondly, the MN should increase the voluntary retirement percentages and the time in grade in the senior grades categories; those above Commander.

B. LIMITATIONS

The optimization model considers three possible alternatives. The first alternative considers the historical "out" probabilities, probabilities to leave the NN, as remaining constant over time while meeting each of the twelve constraints. This assumption is highly improbable to occur. The table in Appendix J shows that the numbers of NSGO leaving the system were larger, and kept increasing, in the last seven years than they were before this period. This trend would be expected to continue in the short and long term. The second alternative assumes that the historical "out" probabilities can be changed in order to reduce the observed NSGO inventory gaps between expected inventory and demand. For these two alternatives, the nine sub-matrices are optimized separately, and later accommodated in the NSGOTPM.

The first alternative, maintaining historical "out" probabilities constant, significantly reduces the gaps between expected inventory and demand in the junior grades categories; however, the gaps in the senior ranks categories remain large. On the other hand, the second approach, varying "out" probabilities, drastically reduces those gaps both in the junior and senior grades. Yet, this alternative suggests immediately retiring large numbers of personnel in the senior grades and practically eliminating separations from the system in the junior categories. The current state of the Mexican Navy would make both extremes difficult to meet in the short term.

Finally, the third alternative uses the complete NSGOTPM, instead of optimizing separately each of the nine sub-matrices. We also assign a weight to each grade to stress the importance of each rank during the optimization process. Moreover, the NS role is considered in this model.

The third alternative results are like to the second ones; however the process of reducing the observed gaps is smoother than the suggested by using the second alternative. Additionally, we link the Naval School performance to the NSGO promotion process. This linkage suggests that we should increase the probability of a student graduating from the NS in order to accelerate the process of reducing the gaps observed among the junior grades.

This research assumes, for the three alternatives, that a student will stay five years in the Naval School, one year as Midshipman and will after this year be promoted to Ensign. Changing any of to these three assumptions will require modifying either the NSTPM or the optimization model or both.

C. FUTURE RESEARCH

1. Defining NSGO Personnel Career Path

An ideal career path for NSGO must be created to clearly define their promotional process. This path should specify the time a NSGO spends at Sea before being appointed to shore commissions. Moreover, the suggested path must define the academic requirements an NSGO must meet before taking office for a particular job.

2. Controlling Grade Rates

A reasonable proportion of Vice Admirals, Rear Admirals, and so on, should exist in order to build a pyramidal like structure of active duty NSGO in the Mexican Navy. Junior and senior grade personnel, all of them under the leadership of the Secretary of the

Navy, must support the base of this structure. The percentages of NSGO in each grade must be determined according to short and long term Mexican Navy missions and objectives.

3. Proposing Limit Time in Grade (TIG)

A method to avoid surpluses of NSGO in senior grades is to establish a Limit Time in Grade (LTG) distribution that clearly defines the time, when necessary, to retire these personnel prior to meeting their mandatory age limit distribution. However, an economic compensation should be created to ease this transition. A monetary recompense is proposed based on grade, seniority, and length-of-service of each NSGO.

4. Improving the Naval School Performance

An educational institution that graduates only 31 % of accessions cannot be viewed as an efficient educational center, regardless of being a civilian or a military institution. Actions must be taken now to increase the probability of graduating an officer from the NS without relaxing educational standards. An increase in NS graduate percentages would close the gaps observed among the junior grade categories much quicker than the current structure.

Improvements to the recruiting process for candidates would reduce the number of attritions during the initial stage of the Naval School. The NS data figure 4 shows that survival rates tend to stabilize after the 12th month, thus increasing, the probability of student graduating from the NS after this first year.

5. Reducing the Number of NSGO Leaving the System

This research found that before a NSGO reaches the grade of Commander a large number leave the Mexican Navy; whereas, after reaching this grade the number of NSGO leaving the system is small. Since the junior grades suffer the largest deficits of NSGO personnel, mechanisms must be implemented to reduce the tendency of these personnel to leave the system regardless of whether or not they have served a mandatory term after graduating from the NS. This mandatory term is in average double the time spent in the NS.

6. Encouraging Retirement

An increase to retired pay percentages could be a reason why NSGO, commencing with grade Commander, remain longer on active duty. Another consideration is that starting at the Commander Grade salaries and special bonuses can be four times larger than retirement pay which increases as grade increases. Changes to these policies could make a difference when NSGO decide whether to retire voluntarily or to continue on active duty until forced to retire.

Based on these two probabilities, an economical compensation model should be created to encourage voluntary retirement among the senior NSGO. This monetary compensation could be computed based on the grade, seniority, and length-of-service of.

APPENDIX A. NAVAL SCHOOL DATA

Month	Month/Class	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
1	1-Aug	149	186	194	165	228	231	228	158	232	268	310	231
2	1-Sep	135	150	145	134	228	195	228	140	209	240	286	191
3	1-Oct	117	129	132	118	228	186	228	125	206	219	281	177
4	1-Nov	107	122	122	110	227	176	223	120	204	203	275	167
5	1-Dec	107	118	119	108	225	168	218	117	197	186	270	166
6	1-Jan	89	104	117	105	223	168	217	114	196	185	270	
7	1-Feb	82	102	110	91	190	160	198	105	174	171	248	
8	1-Mar	82	101	107	88	170	149	190	102	171	169	247	
9	1-Apr	82	101	105	88	146	139	190	102	168	168	227	
10	1-May	80	99	100	87	137	139	189	98	161	166	212	
11	1-Jun	75	98	99	87	135	139	180	87	130	157	202	
12	1-Jul	75	72	91	87	115	132	180	86	126	150	179	
13	2-Aug	75	72	89	74	98	131	180	86	122	148	169	
14	2-Sep	73	72	89	74	98	122	177	85	119	146	148	
15	2-Oct	70	71	89	74	97	121	170	84	119	146	148	
16	2-Nov	70	71	87	74	97	121	124	82	118	142	147	
17	2-Dec	68	71	86	72	97	121	116	76	91	134		
18	2-Jan	68	70	85	62	77	116	115	76	91	133		
19	2-Feb	68	70	82	61	76	85	115	76	85	133		
20	2-Mar	66	69	81	61	76	85	115	74	85	132		
21	2-Apr	65	68	79	61	76	85	114	74	85	124		
22	2-May	62	68	79	60	76	85	114	69	85	124		
23	2-Jun	62	66	78	56	72	84	108	63	85	124		
24	2-Jul	56	65	78	56	71	83	108	63	85	124		
25	3-Aug	56	64	78	56	67	83	108	62	85	116		
26	3-Sep	57	64	78	56	67	83	107	62	85	114		
27	3-Oct	57	64	78	56	65	83	106	58	85	114		
28	3-Nov	56	64	78	56	65	83	106	57	85	113		
29	3-Dec	56	64	77	56	65	83	105	52	85			
30	3-Jan	56	63	68	56	64	83	105	52	85			
31	3-Feb	56	63	68	56	64	83	104	52	85			
32	3-Mar	56	63	68	56	64	83	104	52	85			
33	3-Apr	56	63	68	56	64	82	100	52	82			
34	3-May	56	63	68	56	64	82	99	52	81			
35	3-Jun	55	63	64	56	63	82	99	50	81			
36	3-Jul	55	63	62	56	63	82	97	50	81			
37	4-Aug	55	63	60	56	63	81	95	50	80			
38	4-Sep	55	63	60	56	63	77	95	50	79			
39	4-Oct	55	61	60	56	63	76	93	50	79			
40	4-Nov	55	61	60	56	62	76	84	50	79			
41	4-Dec	55	61	60	56	62	76	79	49				
42	4-Jan	54	61	60	56	62	76	79	49				
43	4-Feb	53	61	60	56	62	76	79	49				
44	4-Mar	53	61	60	56	62	76	79	49				
45	4-Apr	52	61	60	56	62	76	79	49				
46	4-May	51	61	59	56	61	76	79	49				
47	4-Jun	51	61	59	56	61	76	78	49				
48	4-Jul	51	61	59	56	61	76	78	49				
49	5-Aug	51	61	59	56	61	76	78	49				
50	5-Sep	51	61	59	56	61	76	78	49				
51	5-Oct	51	61	59	56	61	76	78	49				
52	5-Nov	50	61	59	56	61	76	78	49				
53	5-Dec	50	61	59	56	61	76	78					
54	5-Jan	49	61	58	56	61	76	78					
55	5-Feb	49	61	58	56	61	76	78					
56	5-Mar	49	61	58	56	60	74	78					
57	5-Apr	48	61	58	56	60	74	78					
58	5-May	48	61	55	56	60	74	78					
59	5-Jun	48	61	55	56	60	74	78					
60	5-Jul	48	61	55	56	60	74	78					

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APPENDIX B. NAVAL SCHOOL SURVIVAL RATE

Month	Month/Class	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
1	1-Aug	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2	1-Sep	0.91	0.81	0.75	0.81	1.00	0.84	1.00	0.89	0.90	0.90	0.92	0.83
3	1-Oct	0.79	0.69	0.68	0.72	1.00	0.81	1.00	0.79	0.89	0.82	0.91	0.77
4	1-Nov	0.72	0.66	0.63	0.67	1.00	0.76	0.98	0.76	0.88	0.76	0.89	0.72
5	1-Dec	0.72	0.63	0.61	0.65	0.99	0.73	0.96	0.74	0.85	0.69	0.87	0.72
6	1-Jan	0.60	0.56	0.60	0.64	0.98	0.73	0.95	0.72	0.84	0.69	0.87	
7	1-Feb	0.55	0.55	0.57	0.55	0.83	0.69	0.87	0.66	0.75	0.64	0.80	
8	1-Mar	0.55	0.54	0.55	0.53	0.75	0.65	0.83	0.65	0.74	0.63	0.80	
9	1-Apr	0.55	0.54	0.54	0.53	0.64	0.60	0.83	0.65	0.72	0.63	0.73	
10	1-May	0.54	0.53	0.52	0.53	0.60	0.60	0.83	0.62	0.69	0.62	0.68	
11	1-Jun	0.50	0.53	0.51	0.53	0.59	0.60	0.79	0.55	0.56	0.59	0.65	
12	1-Jul	0.50	0.39	0.47	0.53	0.50	0.57	0.79	0.54	0.54	0.56	0.58	
13	2-Aug	0.50	0.39	0.46	0.45	0.43	0.57	0.79	0.54	0.53	0.55	0.55	
14	2-Sep	0.49	0.39	0.46	0.45	0.43	0.53	0.78	0.54	0.51	0.54	0.48	
15	2-Oct	0.47	0.38	0.46	0.45	0.43	0.52	0.75	0.53	0.51	0.54	0.48	
16	2-Nov	0.47	0.38	0.45	0.45	0.43	0.52	0.54	0.52	0.51	0.53	0.47	
17	2-Dec	0.46	0.38	0.44	0.44	0.43	0.52	0.51	0.48	0.39	0.50		
18	2-Jan	0.46	0.38	0.44	0.38	0.34	0.50	0.50	0.48	0.39	0.50		
19	2-Feb	0.46	0.38	0.42	0.37	0.33	0.37	0.50	0.48	0.37	0.50		
20	2-Mar	0.44	0.37	0.42	0.37	0.33	0.37	0.50	0.47	0.37	0.49		
21	2-Apr	0.44	0.37	0.41	0.37	0.33	0.37	0.50	0.47	0.37	0.46		
22	2-May	0.42	0.37	0.41	0.36	0.33	0.37	0.50	0.44	0.37	0.46		
23	2-Jun	0.42	0.35	0.40	0.34	0.32	0.36	0.47	0.40	0.37	0.46		
24	2-Jul	0.38	0.35	0.40	0.34	0.31	0.36	0.47	0.40	0.37	0.46		
25	3-Aug	0.38	0.34	0.40	0.34	0.29	0.36	0.47	0.39	0.37	0.43		
26	3-Sep	0.38	0.34	0.40	0.34	0.29	0.36	0.47	0.39	0.37	0.43		
27	3-Oct	0.38	0.34	0.40	0.34	0.29	0.36	0.46	0.37	0.37	0.43		
28	3-Nov	0.38	0.34	0.40	0.34	0.29	0.36	0.46	0.36	0.37	0.42		
29	3-Dec	0.38	0.34	0.40	0.34	0.29	0.36	0.46	0.33	0.37			
30	3-Jan	0.38	0.34	0.35	0.34	0.28	0.36	0.46	0.33	0.37			
31	3-Feb	0.38	0.34	0.35	0.34	0.28	0.36	0.46	0.33	0.37			
32	3-Mar	0.38	0.34	0.35	0.34	0.28	0.36	0.46	0.33	0.37			
33	3-Apr	0.38	0.34	0.35	0.34	0.28	0.35	0.44	0.33	0.35			
34	3-May	0.38	0.34	0.35	0.34	0.28	0.35	0.43	0.33	0.35			
35	3-Jun	0.37	0.34	0.33	0.34	0.28	0.35	0.43	0.32	0.35			
36	3-Jul	0.37	0.34	0.32	0.34	0.28	0.35	0.43	0.32	0.35			
37	4-Aug	0.37	0.34	0.31	0.34	0.28	0.35	0.42	0.32	0.34			
38	4-Sep	0.37	0.34	0.31	0.34	0.28	0.33	0.42	0.32	0.34			
39	4-Oct	0.37	0.33	0.31	0.34	0.28	0.33	0.41	0.32	0.34			
40	4-Nov	0.37	0.33	0.31	0.34	0.27	0.33	0.37	0.32	0.34			
41	4-Dec	0.37	0.33	0.31	0.34	0.27	0.33	0.35	0.31				
42	4-Jan	0.36	0.33	0.31	0.34	0.27	0.33	0.35	0.31				
43	4-Feb	0.36	0.33	0.31	0.34	0.27	0.33	0.35	0.31				
44	4-Mar	0.36	0.33	0.31	0.34	0.27	0.33	0.35	0.31				
45	4-Apr	0.35	0.33	0.31	0.34	0.27	0.33	0.35	0.31				
46	4-May	0.34	0.33	0.30	0.34	0.27	0.33	0.35	0.31				
47	4-Jun	0.34	0.33	0.30	0.34	0.27	0.33	0.34	0.31				
48	4-Jul	0.34	0.33	0.30	0.34	0.27	0.33	0.34	0.31				
49	5-Aug	0.34	0.33	0.30	0.34	0.27	0.33	0.34	0.31				
50	5-Sep	0.34	0.33	0.30	0.34	0.27	0.33	0.34	0.31				
51	5-Oct	0.34	0.33	0.30	0.34	0.27	0.33	0.34	0.31				
52	5-Nov	0.34	0.33	0.30	0.34	0.27	0.33	0.34	0.31				
53	5-Dec	0.34	0.33	0.30	0.34	0.27	0.33	0.34					
54	5-Jan	0.33	0.33	0.30	0.34	0.27	0.33	0.34					
55	5-Feb	0.33	0.33	0.30	0.34	0.27	0.33	0.34					
56	5-Mar	0.33	0.33	0.30	0.34	0.26	0.32	0.34					
57	5-Apr	0.32	0.33	0.30	0.34	0.26	0.32	0.34					
58	5-May	0.32	0.33	0.28	0.34	0.26	0.32	0.34					
59	5-Jun	0.32	0.33	0.28	0.34	0.26	0.32	0.34					
60	5-Jul	0.32	0.33	0.28	0.34	0.26	0.32	0.34					

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APPENDIX C. WEIGHTED AVERAGE SURVIVAL RATE

Month	Month/Class	1991	1992	1993	1994	1995	1996	1997	WAvCR
1	1-Aug	149	186	194	165	228	231	228	1.00
2	1-Sep	135	150	145	134	228	195	228	0.88
3	1-Oct	117	129	132	118	228	186	228	0.82
4	1-Nov	107	122	122	110	227	176	223	0.79
5	1-Dec	107	118	119	108	225	168	218	0.77
6	1-Jan	89	104	117	105	223	168	217	0.74
7	1-Feb	82	102	110	91	190	160	198	0.68
8	1-Mar	82	101	107	88	170	149	190	0.64
9	1-Apr	82	101	105	88	146	139	190	0.62
10	1-May	80	99	100	87	137	139	189	0.60
11	1-Jun	75	98	99	87	135	139	180	0.59
12	1-Jul	75	72	91	87	115	132	180	0.54
13	2-Aug	75	72	89	74	98	131	180	0.52
14	2-Sep	73	72	89	74	98	122	177	0.51
15	2-Oct	70	71	89	74	97	121	170	0.50
16	2-Nov	70	71	87	74	97	121	124	0.47
17	2-Dec	68	71	86	72	97	121	116	0.46
18	2-Jan	68	70	85	62	77	116	115	0.43
19	2-Feb	68	70	82	61	76	85	115	0.40
20	2-Mar	66	69	81	61	76	85	115	0.40
21	2-Apr	65	68	79	61	76	85	114	0.40
22	2-May	62	68	79	60	76	85	114	0.39
23	2-Jun	62	66	78	56	72	84	108	0.38
24	2-Jul	56	65	78	56	71	83	108	0.37
25	3-Aug	56	64	78	56	67	83	108	0.37
26	3-Sep	57	64	78	56	67	83	107	0.37
27	3-Oct	57	64	78	56	65	83	106	0.37
28	3-Nov	56	64	78	56	65	83	106	0.37
29	3-Dec	56	64	77	56	65	83	105	0.37
30	3-Jan	56	63	68	56	64	83	105	0.36
31	3-Feb	56	63	68	56	64	83	104	0.36
32	3-Mar	56	63	68	56	64	83	104	0.36
33	3-Apr	56	63	68	56	64	82	100	0.35
34	3-May	56	63	68	56	64	82	99	0.35
35	3-Jun	55	63	64	56	63	82	99	0.35
36	3-Jul	55	63	62	56	63	82	97	0.35
37	4-Aug	55	63	60	56	63	81	95	0.34
38	4-Sep	55	63	60	56	63	77	95	0.34
39	4-Oct	55	61	60	56	63	76	93	0.34
40	4-Nov	55	61	60	56	62	76	84	0.33
41	4-Dec	55	61	60	56	62	76	79	0.33
42	4-Jan	54	61	60	56	62	76	79	0.32
43	4-Feb	53	61	60	56	62	76	79	0.32
44	4-Mar	53	61	60	56	62	76	79	0.32
45	4-Apr	52	61	60	56	62	76	79	0.32
46	4-May	51	61	59	56	61	76	79	0.32
47	4-Jun	51	61	59	56	61	76	78	0.32
48	4-Jul	51	61	59	56	61	76	78	0.32
49	5-Aug	51	61	59	56	61	76	78	0.32
50	5-Sep	51	61	59	56	61	76	78	0.32
51	5-Oct	51	61	59	56	61	76	78	0.32
52	5-Nov	50	61	59	56	61	76	78	0.32
53	5-Dec	50	61	59	56	61	76	78	0.32
54	5-Jan	49	61	58	56	61	76	78	0.32
55	5-Feb	49	61	58	56	61	76	78	0.32
56	5-Mar	49	61	58	56	60	74	78	0.32
57	5-Apr	48	61	58	56	60	74	78	0.31
58	5-May	48	61	55	56	60	74	78	0.31
59	5-Jun	48	61	55	56	60	74	78	0.31
60	5-Jul	48	61	55	56	60	74	78	0.31

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APPENDIX D. PREDICTED NUMBER OF STUDENTS WHO CONTINUE IN THE NS

Month	Month/Class	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	WAv
1	1-Aug	149	186	194	165	228	231	228	158	232	268	310	231	1.00
2	1-Sep	135	150	145	134	228	195	228	140	209	240	286	191	0.88
3	1-Oct	117	129	132	118	228	186	228	125	206	219	281	177	0.94
4	1-Nov	107	122	122	110	227	176	223	120	204	203	275	167	0.96
5	1-Dec	107	118	119	108	225	168	218	117	197	186	270	166	0.97
6	1-Jan	89	104	117	105	223	168	217	114	196	185	270	163	0.98
7	1-Feb	82	102	110	91	190	160	198	105	174	171	248	148	0.91
8	1-Mar	82	101	107	88	170	149	190	102	171	169	247	144	0.97
9	1-Apr	82	101	105	88	146	139	190	102	168	168	227	138	0.96
10	1-May	80	99	100	87	137	139	189	98	161	166	212	134	0.97
11	1-Jun	75	98	99	87	135	139	180	87	130	157	202	127	0.95
12	1-Jul	75	72	91	87	115	132	180	86	126	150	179	118	0.93
13	2-Aug	75	72	89	74	98	131	180	86	122	148	169	113	0.96
14	2-Sep	73	72	89	74	98	122	177	85	119	146	148	110	0.97
15	2-Oct	70	71	89	74	97	121	170	84	119	146	148	109	0.99
16	2-Nov	70	71	87	74	97	121	124	82	118	142	147	103	0.95
17	2-Dec	68	71	86	72	97	121	116	76	91	134	140	98	0.95
18	2-Jan	68	70	85	62	77	116	115	76	91	133	134	94	0.96
19	2-Feb	68	70	82	61	76	85	115	76	85	133	127	90	0.95
20	2-Mar	66	69	81	61	76	85	115	74	85	132	126	89	0.99
21	2-Apr	65	68	79	61	76	85	114	74	85	124	124	87	0.98
22	2-May	62	68	79	60	76	85	114	69	85	124	122	86	0.99
23	2-Jun	62	66	78	56	72	84	108	63	85	124	119	84	0.97
24	2-Jul	56	65	78	56	71	83	108	63	85	124	117	83	0.99
25	3-Aug	56	64	78	56	67	83	108	62	85	116	115	81	0.98
26	3-Sep	57	64	78	56	67	83	107	62	85	114	115	81	1.00
27	3-Oct	57	64	78	56	65	83	106	58	85	114	114	80	0.99
28	3-Nov	56	64	78	56	65	83	106	57	85	113	114	80	1.00
29	3-Dec	56	64	77	56	65	83	105	52	85	112	113	79	0.99
30	3-Jan	56	63	68	56	64	83	105	52	85	110	111	78	0.98
31	3-Feb	56	63	68	56	64	83	104	52	85	110	111	78	1.00
32	3-Mar	56	63	68	56	64	83	104	52	85	110	111	78	1.00
33	3-Apr	56	63	68	56	64	82	100	52	82	109	109	77	0.99
34	3-May	56	63	68	56	64	82	99	52	81	109	109	77	1.00
35	3-Jun	55	63	64	56	63	82	99	50	81	107	108	76	0.99
36	3-Jul	55	63	62	56	63	82	97	50	81	106	107	76	0.99
37	4-Aug	55	63	60	56	63	81	95	50	80	105	106	75	0.99
38	4-Sep	55	63	60	56	63	77	95	50	79	104	105	74	0.99
39	4-Oct	55	61	60	56	63	76	93	50	79	103	104	73	0.99
40	4-Nov	55	61	60	56	62	76	84	50	79	101	102	72	0.98
41	4-Dec	55	61	60	56	62	76	79	49	78	100	101	71	0.99
42	4-Jan	54	61	60	56	62	76	79	49	78	100	101	71	1.00
43	4-Feb	53	61	60	56	62	76	79	49	78	100	101	71	1.00
44	4-Mar	53	61	60	56	62	76	79	49	78	100	101	71	1.00
45	4-Apr	52	61	60	56	62	76	79	49	78	100	101	71	1.00
46	4-May	51	61	59	56	61	76	79	49	77	99	100	70	0.99
47	4-Jun	51	61	59	56	61	76	78	49	77	99	100	70	1.00
48	4-Jul	51	61	59	56	61	76	78	49	77	99	100	70	1.00
49	5-Aug	51	61	59	56	61	76	78	49	77	99	100	70	1.00
50	5-Sep	51	61	59	56	61	76	78	49	77	99	100	70	1.00
51	5-Oct	51	61	59	56	61	76	78	49	77	99	100	70	1.00
52	5-Nov	50	61	59	56	61	76	78	49	77	99	100	70	1.00
53	5-Dec	50	61	59	56	61	76	78	49	77	99	100	70	1.00
54	5-Jan	49	61	58	56	61	76	78	49	77	99	100	70	1.00
55	5-Feb	49	61	58	56	61	76	78	49	77	99	100	70	1.00
56	5-Mar	49	61	58	56	60	74	78	49	77	98	99	70	0.99
57	5-Apr	48	61	58	56	60	74	78	49	77	98	99	70	1.00
58	5-May	48	61	55	56	60	74	78	48	76	97	98	69	0.99
59	5-Jun	48	61	55	56	60	74	78	48	76	97	98	69	1.00
60	5-Jul	48	61	55	56	60	74	78	48	76	97	98	69	1.00

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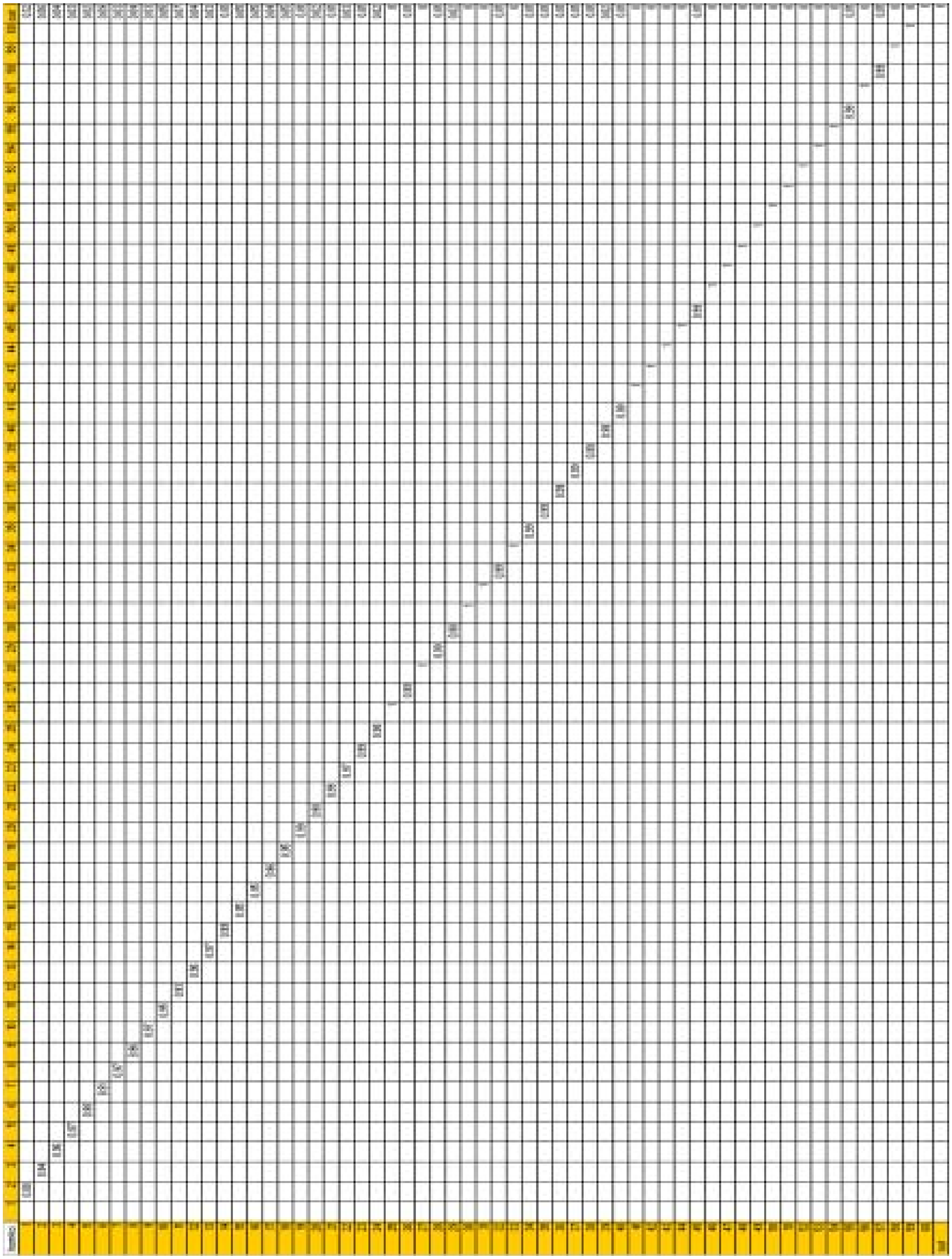
APPENDIX E. NSTPM



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APPENDIX F. NSGO DATA SAMPLES

Active duty sample

KEY NUMBER	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
BORC550721RY0	9	9	8	8	8	8	7	7	7	7	6	6	6	6	5	5	5	5	5	4	4	4	4
BOSD500806V57	8	7	7	7	7	6	6	6	6	6	5	5	5	5	5	4	4	4	4	4	3	3	3
BOSJ441010851	6	5	5	5	5	4	4	4	4	4	4	3	3	3	2	2	2	2	2	2	2	2	2
BOSJ730717SH8	0	0	0	0	0	0	0	0	11	11	11	11	11	10	9	9	9	8	8	8	8	7	7
BUAM720613C69	0	0	0	0	0	0	0	0	0	11	11	11	11	11	10	9	9	9	9	8	8	8	8
BUEJ550211DG9	9	8	8	8	7	7	7	7	6	6	6	6	6	5	5	5	5	5	4	4	4	4	4
BUGF690704CL8	0	0	0	0	0	0	11	11	11	11	11	10	9	9	9	9	9	8	8	8	8	7	7
BUKJ530929HJ5	8	8	8	7	7	7	7	7	6	6	6	6	5	5	5	5	5	4	4	4	4	4	4
BUOR761024JR4	0	0	0	0	0	0	0	0	0	0	0	0	11	11	11	11	11	10	10	9	9	9	8
BUPJ740112S74	0	0	0	0	0	0	0	0	0	11	11	11	11	11	10	9	9	9	9	8	8	8	8
CAAA561224PQ3	9	9	9	8	8	8	8	8	8	7	7	7	7	6	6	6	6	6	5	5	5	5	5
CAAA710801GS0	0	0	0	0	0	0	11	11	11	11	11	11	10	9	9	9	9	8	8	8	8	7	7
CAAA7211048M9	0	0	0	0	0	0	0	0	0	0	11	11	11	11	11	11	10	10	9	9	9	8	8
CAAA7407022D8	0	0	0	0	0	0	0	0	0	11	11	11	11	11	10	9	9	9	9	8	8	8	8
CAAD600722NR4	11	11	11	11	11	10	9	9	9	8	8	8	8	7	7	7	7	6	6	6	6	6	6
CAAE530418F46	8	8	7	7	7	7	7	7	7	7	7	7	7	7	6	6	6	5	5	5	5	4	4
CAAF770707M1A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	11	11	11	11	10	10
CAAG510901DM8	8	8	7	7	7	7	7	6	6	6	6	6	5	5	5	5	5	4	4	4	4	4	4
CAAG640815DQ5	0	11	11	11	11	10	10	9	9	9	9	8	8	8	7	7	7	7	7	6	6	6	6
CAAJ731230JM5	0	0	0	0	0	0	0	0	0	0	0	11	11	11	11	11	10	10	9	9	9	8	8
CAAP390505890	5	5	4	4	4	4	3	3	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1
CAAR7510221L8	0	0	0	0	0	0	0	0	0	0	0	0	11	11	11	11	11	10	10	9	9	9	9

Out of the system sample

KEY NUMBER	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
MULX580424E86	9	9	9	8	8	8	8	8	7	7	7	7	6	6	6	6	6	6	6	6	0	0	0
MUMO590203HR0	11	11	11	11	11	10	9	9	9	9	8	8	8	8	8	8	8	0	0	0	0	0	0
MUOF310904HM4	4	3	3	3	3	3	2	2	2	2	2	2	2	2	2	2	0	0	0	0	0	0	0
MUOF390422V78	4	4	4	4	4	4	4	4	3	3	3	3	3	3	3	3	3	2	2	2	2	2	0
MUOG3003193I8	3	3	3	3	3	3	2	2	2	2	2	2	2	2	2	0	0	0	0	0	0	0	0
MURF3405186A7	4	4	4	4	4	4	3	3	3	3	3	3	3	3	0	0	0	0	0	0	0	0	0
MURV710730GI9	0	0	0	0	0	0	0	0	0	11	11	11	11	11	10	9	9	9	9	9	0	0	0
MUSM710528UF0	0	0	0	0	0	0	0	0	11	11	11	11	11	10	9	9	0	0	0	0	0	0	0
MUVA390404MP8	4	4	4	3	3	3	3	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2	0
NACI460814ND0	7	7	6	6	6	6	6	5	5	5	5	5	5	4	4	4	4	4	4	4	4	4	0
NASO7001191I7	0	0	0	0	0	0	11	11	11	11	11	10	9	9	9	9	9	8	8	8	8	0	0
NEFM581116IL1	11	11	11	11	10	10	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NEPL540825KW0	8	8	8	8	8	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NERJ561220DS4	9	9	9	8	8	8	8	8	7	7	7	7	6	6	6	6	6	6	6	6	6	0	0
NIEJ770217U81	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	11	11	11	11	10	10	0
NUEG3103212N7	3	3	2	2	2	2	2	2	2	2	2	2	2	1	1	1	1	0	0	0	0	0	0
NUEM340130MB8	4	4	4	3	3	3	3	3	3	2	2	2	2	2	2	2	1	1	1	1	0	0	0
OAEJ4107108R8	7	6	6	6	5	5	5	5	5	5	4	4	4	4	4	0	0	0	0	0	0	0	0
OEBT271220GM2	3	3	2	2	2	2	2	2	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0
OEHE401013GH6	5	5	5	5	5	5	5	4	4	4	4	4	4	4	4	4	4	3	3	3	3	3	0
OELO631005I60	11	11	11	11	11	10	9	9	9	9	8	8	8	8	7	7	7	7	7	7	7	7	0

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APPENDIX G. DISTRIBUTION OF THE NSGO PERSONNEL INVENTORY

Rank/Year	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
9*1	70	93	86	29	106	112	2	439	139	143	132	63	2	48	60	50	56
9*2	45	70	92	86	29	105	112	2	438	139	142	132	63	2	48	60	50
9*3	67	45	69	91	84	29	105	112	2	328	136	137	132	62	2	48	60
9*4	28	28	45	8	29	84	29	74	74	1	137	80	46	132	62	2	3
9*5	16	0	12	17	1	7	17	15	48	33	0	68	17	16	18	7	0
9*6+	1	1	1	5	3	4	8	18	23	36	24	18	23	25	27	24	10
8*1	40	80	15	97	87	22	69	49	73	182	232	120	203	37	125	69	59
8*2	40	40	80	15	96	87	22	69	49	73	182	232	120	201	37	125	69
8*3	101	40	40	78	15	96	87	22	68	49	73	182	229	118	198	37	124
8*4	110	101	40	36	68	15	96	39	7	11	3	8	13	225	115	194	1
8*5	5	65	99	14	9	53	15	39	20	2	3	2	5	6	27	7	3
8*6+	2	2	10	24	6	8	31	16	25	18	8	8	4	5	6	9	4
7*1	19	45	54	112	68	20	30	131	62	87	60	70	174	8	201	125	231
7*2	27	18	45	53	111	68	20	30	131	62	87	60	70	174	8	201	125
7*3	83	26	16	45	52	110	68	20	29	130	61	86	59	69	169	8	201
7*4	54	78	25	16	39	52	110	67	16	20	116	46	86	57	69	167	8
7*5	8	20	78	6	2	24	52	47	29	8	12	83	7	86	56	8	17
7*6+	1	3	5	19	7	6	10	31	34	34	17	17	20	16	29	28	11
6*1	28	45	22	83	39	18	19	90	84	43	46	58	117	10	72	119	172
6*2	21	28	45	22	83	39	18	19	90	84	43	46	58	117	10	72	119
6*3	36	21	28	45	22	83	39	18	19	88	84	43	46	58	115	10	72
6*4	36	36	21	24	45	22	83	39	11	11	83	81	41	45	57	114	10
6*5	16	32	36	12	19	44	22	44	17	4	5	78	69	41	45	3	48
6*6+	12	6	26	18	4	7	39	29	42	27	17	13	10	15	14	10	3
5*1	16	27	12	57	31	16	12	71	58	45	23	17	93	61	40	100	73
5*2	17	16	27	12	57	31	16	12	71	58	45	23	17	93	61	40	100
5*3	24	17	16	26	12	57	31	16	12	71	58	45	23	17	93	61	40
5*4	24	24	17	14	26	12	57	31	16	11	70	58	45	22	16	91	61
5*5	18	19	24	17	11	26	12	24	16	11	11	70	56	44	22	10	65
5*6+	18	13	20	9	5	10	31	25	37	38	28	27	35	40	38	45	26
4*1	12	28	12	38	24	6	5	48	25	17	20	11	63	50	44	22	52
4*2	10	12	28	12	38	24	6	5	48	25	17	20	11	63	50	44	22
4*3	15	10	12	28	11	38	24	6	5	48	25	17	20	11	63	50	44
4*4	20	15	10	9	27	11	37	23	6	5	48	25	17	20	11	63	50
4*5	18	19	15	9	9	27	11	27	15	1	5	48	22	17	20	11	63
4*6+	33	24	38	40	27	30	48	46	63	67	48	33	45	45	38	40	46
3*1	8	28	5	17	24	6	9	22	15	15	16	15	39	22	21	12	0
3*2	4	7	28	5	17	24	6	9	22	15	15	16	15	39	22	21	12
3*3	15	4	7	26	5	17	24	6	8	20	15	15	16	15	39	22	21
3*4	13	15	4	7	26	5	17	24	6	6	20	15	15	16	15	38	22
3*5	8	14	15	4	7	26	5	14	21	3	6	19	15	15	16	14	38
3*6+	9	4	16	22	16	20	41	39	41	57	44	36	21	23	36	40	45
2*1	4	13	2	11	10	3	5	8	13	8	10	13	27	13	0	11	0
2*2	0	4	13	2	11	10	3	5	8	13	8	10	13	27	13	0	11
2*3	5	0	4	13	2	11	10	3	5	8	13	8	10	13	27	13	0
2*4	7	5	0	4	13	2	11	10	3	5	8	13	8	10	13	26	13
2*5	2	7	5	0	4	13	2	11	9	3	5	8	13	8	10	10	23
2*6+	1	2	9	11	9	12	24	25	33	35	27	20	20	30	34	35	34
1*1	2	1	0	3	2	0	0	1	3	2	0	10	0	0	0	12	0
1*2	0	2	1	0	3	2	0	0	1	3	2	0	10	0	0	0	12
1*3	0	0	2	1	0	3	2	0	0	1	3	2	0	10	0	0	0
1*4	0	0	0	2	1	0	3	2	0	0	1	3	2	0	9	0	0
1*5	1	0	0	0	2	1	0	3	1	0	0	1	2	2	0	7	0
1*6+	0	1	1	1	0	2	3	3	6	3	2	2	2	3	5	5	6

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APPENDIX H. DISTRIBUTION OF THE NSGO PERSONNEL PROMOTED

Rank/Year	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
9*1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9*2	0	0	1	2	0	0	0	0	110	0	0	0	0	0	0	0	0
9*3	38	0	61	61	0	0	29	38	1	190	53	90	0	0	0	44	42
9*4	27	15	28	7	22	67	14	26	40	1	66	61	29	112	55	2	1
9*5	14	0	7	14	0	1	5	7	23	24	0	44	3	6	10	4	0
9*6+	1	0	0	3	0	1	1	2	8	17	1	8	5	7	4	9	3
8*1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8*2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8*3	0	0	3	10	0	0	48	15	57	44	65	167	0	1	0	36	24
8*4	45	0	25	27	15	0	57	19	4	7	1	3	5	196	104	184	1
8*5	3	55	76	12	4	28	5	21	13	1	0	1	3	3	17	5	2
8*6+	0	1	7	19	1	2	21	7	13	8	3	3	0	1	4	6	4
7*1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7*2	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
7*3	3	1	1	6	0	0	0	3	9	13	14	0	0	0	2	0	10
7*4	34	1	19	14	15	0	59	37	7	8	33	39	0	0	61	150	6
7*5	6	17	61	6	1	19	29	27	11	5	8	70	3	69	47	6	2
7*6+	0	1	1	12	2	0	2	17	16	20	3	8	7	3	9	16	1
6*1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6*2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6*3	0	0	4	0	0	0	0	7	7	4	3	1	0	0	0	0	0
6*4	4	0	9	5	0	0	39	21	7	6	5	12	0	0	54	66	0
6*5	12	7	24	12	13	12	12	19	8	3	5	73	60	37	40	2	10
6*6+	10	5	20	14	3	0	20	11	22	10	4	7	1	3	6	5	1
5*1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5*2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5*3	0	0	1	0	0	0	0	0	1	0	0	0	0	0	2	0	0
5*4	6	0	0	3	0	0	33	15	9	0	0	2	0	0	6	24	0
5*5	13	7	22	14	5	0	4	4	5	5	7	54	41	35	13	6	3
5*6+	9	5	14	7	1	5	11	6	6	15	4	7	9	9	1	22	3
4*1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4*2	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
4*3	0	0	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0
4*4	1	0	1	0	0	0	10	7	5	0	0	3	0	0	0	0	0
4*5	8	0	0	1	1	0	0	4	4	0	3	27	8	12	7	0	0
4*6+	19	5	13	21	5	9	12	4	6	16	12	9	14	9	5	0	0
3*1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3*2	0	0	2	0	0	0	0	0	2	0	0	0	0	0	0	0	0
3*3	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
3*4	0	0	0	0	0	0	2	2	3	0	0	0	0	0	0	0	0
3*5	6	0	1	1	0	0	0	4	0	0	3	15	8	0	1	0	0
3*6+	7	2	8	9	3	5	6	7	1	10	10	12	5	0	10	0	0
2*1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2*2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2*3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2*4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0
2*5	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
2*6+	1	0	3	2	0	0	1	3	2	0	9	0	0	0	9	0	0
1*1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1*2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1*3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1*4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1*5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1*6+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

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APPENDIX I. DISTRIBUTION OF THE NSGO PERSONNEL NOT PROMOTED

Rank/Year	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
9*1	70	92	86	29	105	112	2	438	139	142	132	63	2	48	60	50	56
9*2	45	69	91	84	29	105	112	2	328	136	137	132	62	2	48	60	50
9*3	28	45	8	29	84	29	74	74	1	137	80	46	132	62	2	3	18
9*4	0	12	17	1	7	17	15	48	33	0	68	17	16	18	7	0	0
9*5	1	0	4	2	1	6	11	8	23	8	0	16	11	9	4	0	0
9*6+	0	1	1	1	3	2	7	15	13	16	19	7	14	18	20	10	4
8*1	40	80	14	96	87	22	69	49	73	182	232	120	201	37	125	69	59
8*2	40	40	79	15	96	87	22	68	49	73	182	229	118	198	37	124	67
8*3	101	40	36	68	15	96	39	7	11	3	8	13	225	115	194	1	98
8*4	62	99	14	9	53	15	39	20	2	3	2	5	6	27	7	3	0
8*5	2	8	22	2	4	25	8	17	7	1	3	0	2	3	8	2	0
8*6+	1	1	2	4	4	6	8	8	11	7	5	4	3	3	1	2	0
7*1	18	45	53	111	68	20	30	130	61	86	60	70	174	8	201	125	230
7*2	26	17	45	52	110	68	20	30	131	62	86	59	69	169	8	201	124
7*3	79	25	15	39	52	110	67	16	20	116	46	86	57	69	167	8	189
7*4	20	77	6	2	24	52	47	29	8	12	83	7	86	56	8	17	2
7*5	2	3	16	0	1	5	23	20	17	3	4	12	4	16	9	0	14
7*6+	1	2	4	7	5	5	8	14	17	14	13	8	12	13	19	11	6
6*1	28	45	22	83	39	18	19	90	84	43	46	58	117	10	72	119	172
6*2	21	28	45	22	83	39	18	19	88	84	43	46	58	115	10	72	119
6*3	36	21	24	45	22	83	39	11	12	83	81	41	45	57	114	10	72
6*4	32	36	12	19	44	22	44	17	4	5	78	69	41	45	3	48	10
6*5	4	25	12	0	6	32	10	25	8	1	0	5	9	4	5	1	38
6*6+	2	1	6	4	1	7	19	17	19	16	13	5	6	10	5	2	1
5*1	16	27	12	57	31	16	12	71	58	45	23	17	93	61	40	100	73
5*2	17	16	26	12	57	31	16	12	71	58	45	23	17	93	61	40	100
5*3	24	17	15	26	12	57	31	16	11	70	58	45	22	16	91	61	40
5*4	18	24	17	11	26	12	24	16	7	11	70	56	44	22	10	65	61
5*5	5	12	2	3	6	26	7	19	11	6	4	15	15	9	8	4	62
5*6+	9	8	6	2	4	5	18	18	27	22	23	20	25	29	37	22	23
4*1	12	28	12	38	24	6	5	48	25	17	20	11	63	50	44	22	52
4*2	10	12	28	11	38	24	6	5	48	25	17	20	11	63	50	44	22
4*3	15	10	9	27	11	37	23	6	5	48	25	17	20	11	63	50	44
4*4	19	15	9	9	27	11	27	15	1	5	48	22	17	20	11	63	50
4*5	10	19	15	8	8	27	11	21	11	0	2	21	14	5	13	11	63
4*6+	14	19	25	19	22	21	35	42	56	48	31	24	31	33	27	35	44
3*1	8	28	5	17	24	6	9	22	15	15	16	15	39	22	21	12	0
3*2	4	7	26	5	17	24	6	8	20	15	15	16	15	39	22	21	12
3*3	15	4	7	26	5	17	24	6	6	20	15	15	16	15	38	22	21
3*4	13	15	4	7	26	5	14	21	3	6	19	15	15	16	14	38	22
3*5	2	14	14	3	7	26	5	10	21	3	3	4	7	15	15	14	38
3*6+	2	2	8	13	13	15	34	31	36	41	33	17	16	21	25	31	43
2*1	4	13	2	11	10	3	5	8	13	8	10	13	27	13	0	11	0
2*2	0	4	13	2	11	10	3	5	8	13	8	10	13	27	13	0	11
2*3	5	0	4	13	2	11	10	3	5	8	13	8	10	13	26	13	0
2*4	7	5	0	4	13	2	11	9	3	5	8	13	8	10	10	23	13
2*5	2	7	5	0	4	13	2	11	9	3	4	8	13	8	10	6	23
2*6+	0	2	6	9	8	11	23	22	26	24	16	12	17	26	25	28	30
1*1	2	1	0	3	2	0	0	1	3	2	0	10	0	0	0	12	0
1*2	0	2	1	0	3	2	0	0	1	3	2	0	10	0	0	0	12
1*3	0	0	2	1	0	3	2	0	0	1	3	2	0	9	0	0	0
1*4	0	0	0	2	1	0	3	1	0	0	1	2	2	0	7	0	0
1*5	1	0	0	0	2	1	0	3	0	0	0	0	1	2	0	1	0
1*6+	0	1	1	0	0	2	3	3	3	2	2	2	2	3	5	5	4

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APPENDIX J. DISTRIBUTION OF THE NSGO PERSONNEL WHO LEFT THE MN

Rank/Year	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
9*1	0	1	0	0	1	0	0	1	0	1	0	0	0	0	0	0	0
9*2	0	1	0	0	0	0	0	0	0	3	5	0	1	0	0	0	0
9*3	1	0	0	1	0	0	2	0	0	1	3	1	0	0	0	1	0
9*4	1	1	0	0	0	0	0	0	1	0	3	2	1	2	0	0	2
9*5	1	0	1	1	0	0	1	0	2	1	0	8	3	1	4	3	0
9*6+	0	0	0	1	0	1	0	1	2	3	4	3	4	0	3	5	3
8*1	0	0	1	1	0	0	0	0	0	0	0	0	2	0	0	0	0
8*2	0	0	0	0	0	0	0	1	0	0	0	3	2	3	0	1	2
8*3	0	0	1	0	0	0	0	0	0	2	0	2	4	2	4	0	2
8*4	3	2	1	0	0	0	0	0	1	1	0	0	2	2	4	7	0
8*5	0	2	1	0	1	0	2	1	0	0	0	1	0	0	2	0	1
8*6+	1	0	1	1	1	0	2	1	1	3	0	1	1	1	1	1	0
7*1	0	0	0	1	0	0	0	1	1	1	0	0	0	0	0	0	1
7*2	0	0	0	0	1	0	0	0	0	0	1	1	1	5	0	0	1
7*3	1	0	0	0	0	0	1	1	0	1	1	0	2	0	0	0	2
7*4	0	0	0	0	0	0	4	1	1	0	0	0	0	1	0	0	0
7*5	0	0	1	0	0	0	0	0	1	0	0	1	0	1	0	2	1
7*6+	0	0	0	0	0	1	0	0	1	0	1	1	1	0	1	1	4
6*1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6*2	0	0	0	0	0	0	0	0	2	0	0	0	0	2	0	0	0
6*3	0	0	0	0	0	0	0	0	0	1	0	1	1	1	1	0	0
6*4	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0
6*5	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
6*6+	0	0	0	0	0	0	0	1	1	1	0	1	3	2	3	3	1
5*1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5*2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5*3	0	0	0	0	0	0	0	0	0	1	0	0	1	1	0	0	0
5*4	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	2	0
5*5	0	0	0	0	0	0	1	1	0	0	0	1	0	0	1	0	0
5*6+	0	0	0	0	0	0	2	1	4	1	1	0	1	2	0	1	0
4*1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4*2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4*3	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0
4*4	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
4*5	0	0	0	0	0	0	0	2	0	1	0	0	0	0	0	0	0
4*6+	0	0	0	0	0	0	1	0	1	3	5	0	0	3	6	5	2
3*1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3*2	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
3*3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
3*4	0	0	0	0	0	0	1	1	0	0	1	0	0	0	1	0	0
3*5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3*6+	0	0	0	0	0	0	1	1	4	6	1	7	0	2	1	9	2
2*1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2*2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2*3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
2*4	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	3	0
2*5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0
2*6+	0	0	0	0	1	1	0	0	5	11	2	8	3	4	0	7	4
1*1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1*2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1*3	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
1*4	0	0	0	0	0	0	0	1	0	0	0	1	0	0	2	0	0
1*5	0	0	0	0	0	0	0	0	1	0	0	1	1	0	0	6	0
1*6+	0	0	0	1	0	0	0	0	3	1	0	0	0	0	0	0	2

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APPENDIX K. TRANSITION PROBABILITIES

Rank / Seniority	Probability of being promoted	Probability of not being promoted	Probability of leaving
9*1	0.00	1.00	0.00
9*2	0.07	0.92	0.01
9*3	0.43	0.56	0.01
9*4	0.66	0.32	0.02
9*5	0.55	0.36	0.09
9*6+	0.28	0.60	0.12
8*1	0.00	1.00	0.00
8*2	0.00	0.99	0.01
8*3	0.30	0.69	0.01
8*4	0.64	0.34	0.02
8*5	0.67	0.30	0.03
8*6+	0.54	0.38	0.09
7*1	0.00	1.00	0.00
7*2	0.00	0.99	0.01
7*3	0.05	0.94	0.01
7*4	0.47	0.52	0.01
7*5	0.71	0.27	0.01
7*6+	0.41	0.55	0.04
6*1	0.00	1.00	0.00
6*2	0.00	1.00	0.00
6*3	0.03	0.96	0.01
6*4	0.30	0.70	0.00
6*5	0.65	0.35	0.00
6*6+	0.49	0.46	0.05
5*1	0.00	1.00	0.00
5*2	0.00	1.00	0.00
5*3	0.01	0.99	0.00
5*4	0.16	0.83	0.01
5*5	0.52	0.47	0.01
5*6+	0.30	0.67	0.03
4*1	0.00	1.00	0.00
4*2	0.00	1.00	0.00
4*3	0.01	0.99	0.00
4*4	0.07	0.93	0.00
4*5	0.22	0.77	0.01
4*6+	0.22	0.74	0.04
3*1	0.00	1.00	0.00
3*2	0.01	0.98	0.00
3*3	0.01	0.99	0.00
3*4	0.03	0.96	0.02
3*5	0.16	0.84	0.00
3*6+	0.19	0.75	0.07
2*1	0.00	1.00	0.00
2*2	0.00	1.00	0.00
2*3	0.00	0.99	0.01
2*4	0.02	0.95	0.03
2*5	0.01	0.96	0.03
2*6+	0.08	0.79	0.13
1*1	0.00	1.00	0.00
1*2	0.00	1.00	0.00
1*3	0.00	0.96	0.04
1*4	0.00	0.83	0.17
1*5	0.00	0.55	0.45
1*6+	0.00	0.84	0.16

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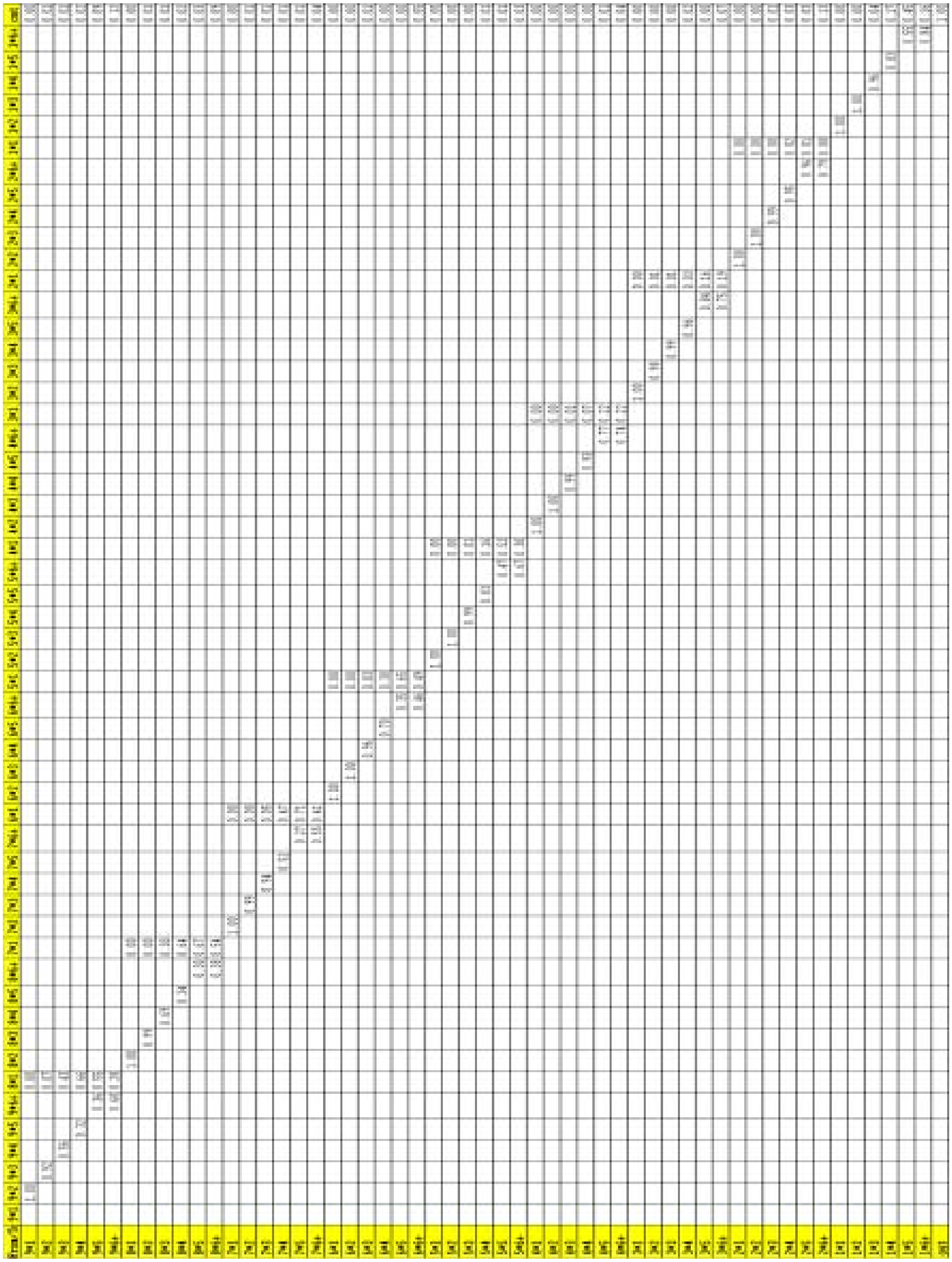
APPENDIX L. NSGOTPM



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APPENDIX M. LENGTH-OF-SERVICE DISTRIBUTION

Month	Transition Probabilities	Entering Number Class 1998	Continuing Number in Month j Class 1998	Entering Number Class 2003	Continuing Number in Month j Class 2003
1	1.00	158	158	231	231
2	0.88	0	140	0	204
3	0.94	0	131	0	192
4	0.96	0	126	0	184
5	0.97	0	122	0	179
6	0.98	0	119	0	175
7	0.91	0	109	0	159
8	0.97	0	105	0	154
9	0.96	0	101	0	148
10	0.97	0	98	0	143
11	0.95	0	93	0	136
12	0.93	0	86	0	126
13	0.96	0	83	0	121
14	0.97	0	80	0	117
15	0.99	0	79	0	116
16	0.95	0	76	0	111
17	0.95	0	72	0	105
18	0.96	0	69	0	100
19	0.95	0	65	0	95
20	0.99	0	65	0	95
21	0.98	0	64	0	93
22	0.99	0	63	0	92
23	0.97	0	61	0	90
24	0.99	0	61	0	89
25	0.98	0	59	0	87
26	1.00	0	59	0	87
27	0.99	0	59	0	86
28	1.00	0	59	0	86
29	0.99	0	58	0	85
30	0.98	0	57	0	83
31	1.00	0	57	0	83
32	1.00	0	57	0	83
33	0.99	0	56	0	82
34	1.00	0	56	0	82
35	0.99	0	55	0	81
36	0.99	0	55	0	80
37	0.99	0	54	0	79
38	0.99	0	54	0	79
39	0.99	0	53	0	78
40	0.98	0	53	0	77
41	0.99	0	52	0	76
42	1.00	0	52	0	76
43	1.00	0	52	0	76
44	1.00	0	52	0	76
45	1.00	0	52	0	75
46	0.99	0	51	0	75
47	1.00	0	51	0	75
48	1.00	0	51	0	75
49	1.00	0	51	0	75
50	1.00	0	51	0	75
51	1.00	0	51	0	75
52	1.00	0	51	0	75
53	1.00	0	51	0	75
54	1.00	0	51	0	74
55	1.00	0	51	0	74
56	0.99	0	50	0	74
57	1.00	0	50	0	74
58	0.99	0	50	0	73
59	1.00	0	50	0	73
60	1.00	0	50	0	73

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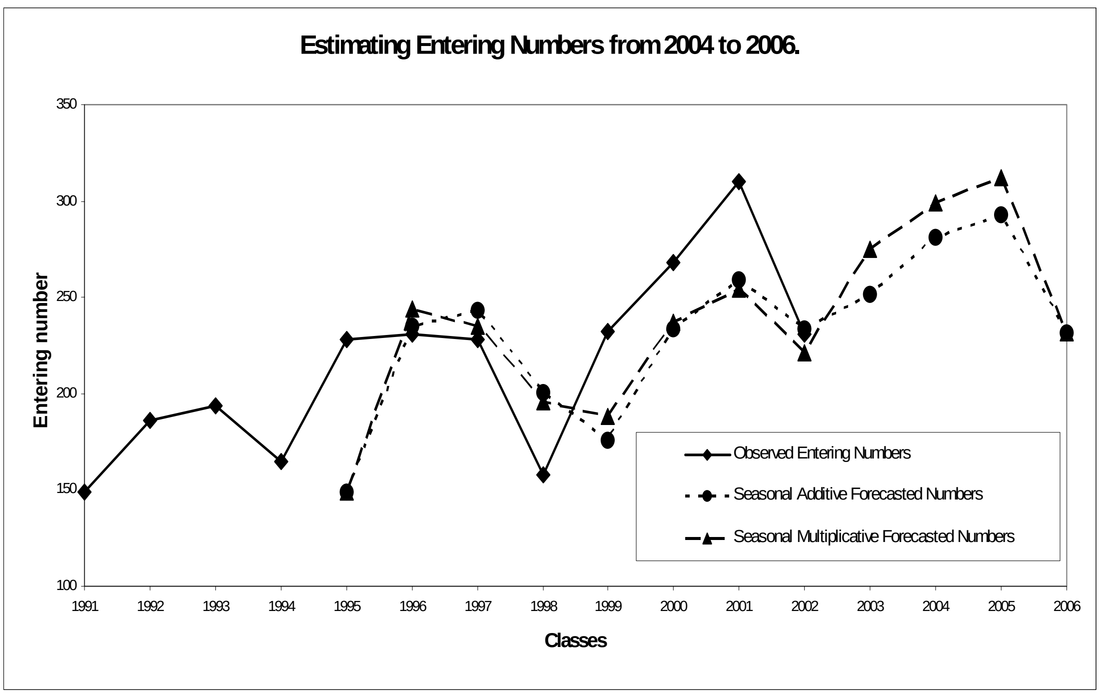
APPENDIX N. ESTIMATED ENTERING NUMBERS TO THE NAVAL SCHOOL FROM 2003 TO 2006

Periodicity	Class	Observed Entering Numbers	Level	Seasonal Factor	Seasonal Additive Forecasted Numbers		
1	1991	149	173.50	0.86			
2	1992	186	173.50	1.07		alpha=	0.4976
3	1993	194	173.50	1.12		beta=	0.3977
4	1994	165	173.50	0.95			
1	1995	228	219.27	0.93	149.00		
2	1996	231	217.38	1.07	235.07		
3	1997	228	210.68	1.10	243.07		
4	1998	158	188.52	0.91	200.36		
1	1999	232	218.74	0.98	175.47		
2	2000	268	234.72	1.10	233.68		
3	2001	310	257.67	1.14	259.10		
4	2002	231	256.31	0.90	233.47		
1	2003				251.80		
2	2004				281.30		
3	2005				293.04		
4	2006				231.75		
				SME=	1906.15		



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APPENDIX O. UNCONSTRAINED ESTIMATED NSGO PERSONNEL DISTRIBUTION FROM 2003 THROUGH 2012

Rank/Year	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
9*1	58	72	48	74	86	99	74	81	90	94	74
9*2	56	58	72	48	74	86	99	74	80	90	94
9*3	50	52	53	66	44	68	79	91	68	74	83
9*4	18	28	29	30	37	25	39	45	52	38	42
9*5	0	6	9	9	10	12	8	12	14	17	12
9*6+	4	2	4	5	7	7	9	8	9	11	12
8*1	46	38	49	53	59	56	61	73	83	80	76
8*2	59	46	38	49	53	58	56	60	73	83	79
8*3	67	59	45	38	48	53	58	56	60	73	82
8*4	97	46	40	31	26	33	36	40	38	41	50
8*5	0	33	16	14	11	9	11	12	13	13	14
8*6+	0	0	10	9	7	6	5	5	6	6	6
7*1	31	82	69	55	45	42	46	51	53	55	60
7*2	231	31	82	69	55	45	42	46	51	53	54
7*3	123	229	31	81	68	54	44	42	46	50	53
7*4	188	116	215	29	76	64	51	42	39	43	47
7*5	2	98	61	113	15	40	33	27	22	21	22
7*6+	19	11	33	35	50	32	29	25	21	18	15
6*1	19	104	141	160	112	71	75	62	51	45	45
6*2	176	19	104	141	160	112	71	75	62	51	45
6*3	119	175	19	104	140	159	112	71	74	62	51
6*4	71	115	169	18	100	135	153	108	68	71	60
6*5	10	49	80	118	13	70	94	107	75	47	50
6*6+	39	21	27	40	59	31	39	50	60	53	41
5*1	11	51	83	116	105	71	106	130	129	101	80
5*2	73	11	51	83	116	105	71	106	130	129	101
5*3	100	73	11	50	82	116	105	71	106	129	129
5*4	40	99	72	11	50	82	115	104	71	105	128
5*5	61	33	82	60	9	41	68	95	86	59	87
5*6+	83	84	72	87	86	62	61	73	93	103	96
4*1	6	64	59	77	60	40	55	73	89	85	80
4*2	52	6	64	59	77	60	40	55	73	89	85
4*3	23	52	6	64	59	76	59	39	54	73	89
4*4	44	23	51	6	63	58	75	59	39	54	72
4*5	50	41	21	48	5	59	54	70	54	36	50
4*6+	106	117	118	103	113	88	110	123	145	149	138
3*1	0	38	37	35	35	32	38	42	48	48	46
3*2	0	0	38	37	35	35	32	38	42	48	48
3*3	12	0	0	37	37	34	34	31	37	42	47
3*4	20	12	0	0	37	36	34	34	31	36	41
3*5	21	19	11	0	0	36	35	32	32	29	35
3*6+	72	71	69	61	46	34	55	70	80	87	89
2*1	0	17	17	15	12	10	14	18	20	22	23
2*2	0	0	17	17	15	12	10	14	18	20	22
2*3	11	0	0	17	17	15	12	10	14	18	20
2*4	0	11	0	0	17	17	15	12	10	14	17
2*5	13	0	10	0	0	17	16	15	12	10	13
2*6+	37	42	33	36	28	22	34	42	47	48	47
1*1	0	3	4	3	3	3	2	3	4	4	4
1*2	0	0	3	4	3	3	3	2	3	4	4
1*3	12	0	0	3	4	3	3	3	2	3	4
1*4	0	12	0	0	3	4	3	3	3	2	3
1*5	0	0	10	0	0	3	3	2	2	2	2
1*6+	4	3	3	8	6	5	6	7	7	7	7

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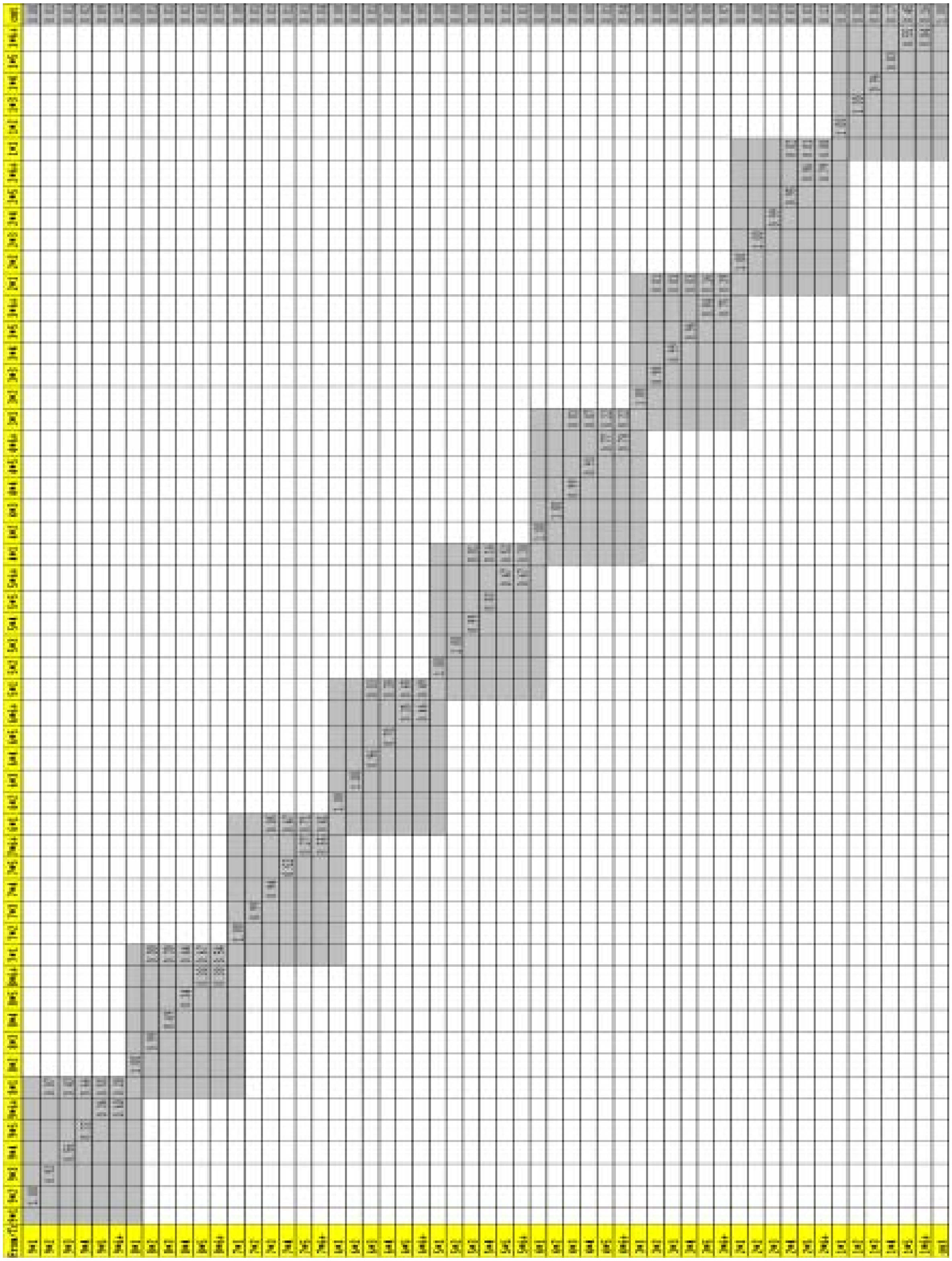
APPENDIX P. UNCONSTRAINED NSGOTPM



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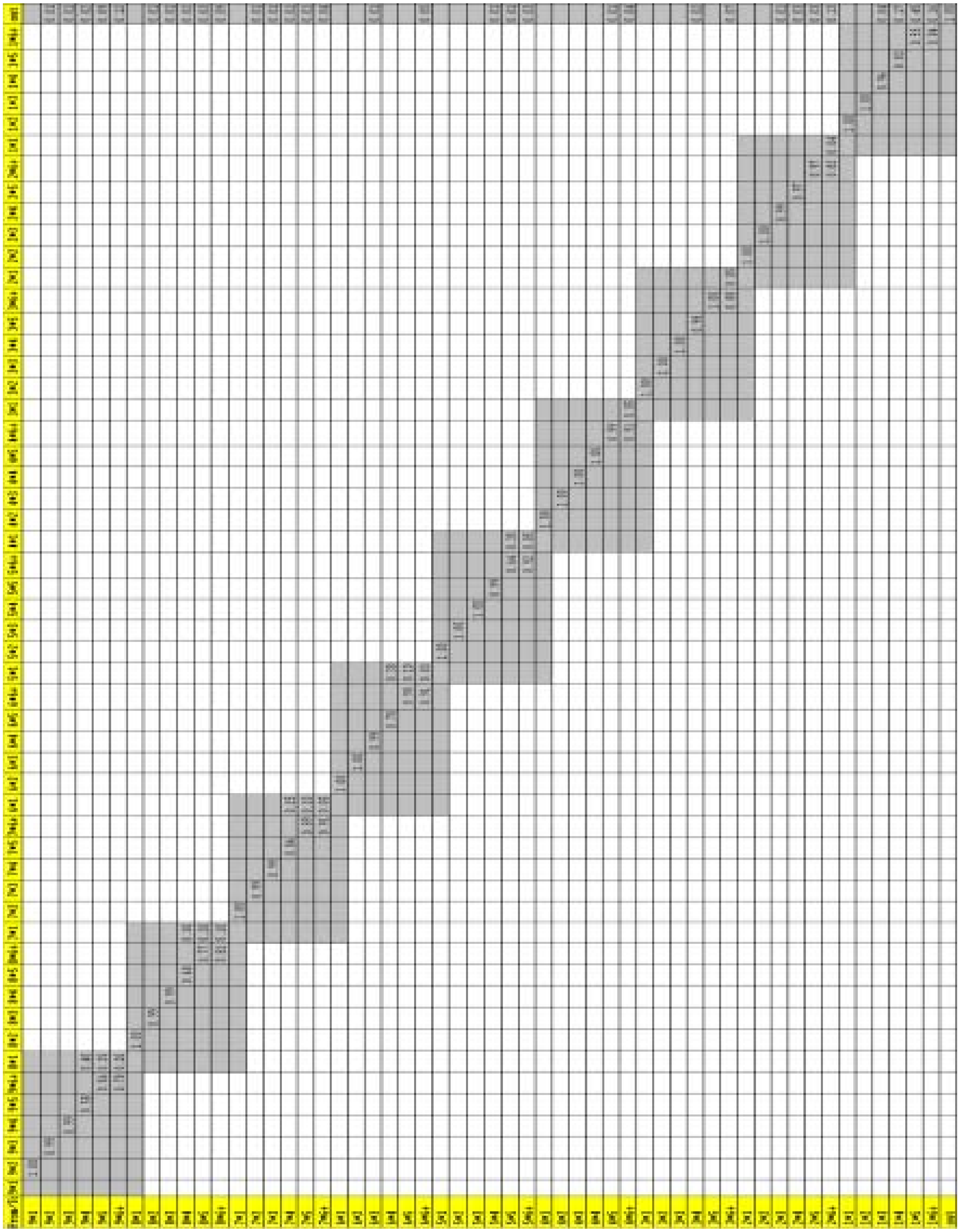
APPENDIX Q. CONSTRAINED NSGOTPM WHILE MAINTAINING THE "OUT" PROBABILITIES CONSTANT



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APPENDIX R. CONSTRAINED ESTIMATED NSGO PERSONNEL DISTRIBUTION FROM 2003 THROUGH 2012 WHILE MAINTAINING THE "OUT" PROBABILITIES CONSTANT

Rank/Year	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
9*1	58	72	48	72	83	96	72	78	87	91	72
9*2	56	58	72	48	72	83	96	71	78	87	91
9*3	50	56	57	71	48	71	82	95	71	77	86
9*4	18	50	55	57	71	47	71	82	95	71	77
9*5	0	11	29	32	33	41	28	41	48	55	41
9*6+	4	3	8	23	36	47	60	62	72	83	96
8*1	46	8	24	33	36	44	38	44	53	62	56
8*2	59	46	8	24	33	36	44	38	44	53	62
8*3	67	59	45	8	24	33	36	43	38	44	53
8*4	97	66	58	45	7	23	32	36	43	37	43
8*5	0	66	45	39	31	5	16	22	24	29	25
8*6+	0	0	51	76	92	98	84	81	83	86	92
7*1	31	29	33	31	29	18	18	21	23	26	26
7*2	231	31	29	33	31	29	17	18	21	23	26
7*3	123	228	31	29	33	31	29	17	18	21	23
7*4	188	122	227	30	29	32	31	28	17	18	21
7*5	2	159	103	191	26	24	27	26	24	15	15
7*6+	19	19	158	235	384	373	361	354	346	337	320
6*1	19	29	35	52	35	26	26	25	25	22	21
6*2	176	19	29	35	52	35	26	26	25	25	22
6*3	119	171	19	29	35	52	35	26	26	25	24
6*4	71	118	170	19	29	35	52	35	26	26	25
6*5	10	50	83	119	13	20	24	36	25	18	18
6*6+	39	45	85	152	246	237	234	236	248	248	243
5*1	11	23	42	62	22	18	20	25	22	18	17
5*2	73	11	23	42	62	22	18	20	25	22	18
5*3	100	73	11	23	42	62	22	18	20	25	22
5*4	40	100	73	11	23	41	61	22	18	20	25
5*5	61	40	99	72	11	23	41	61	22	18	20
5*6+	83	116	132	185	217	206	205	215	237	233	226
4*1	6	26	20	41	35	15	18	25	32	20	18
4*2	52	6	26	20	41	35	15	18	25	32	20
4*3	23	52	6	26	20	41	35	15	18	25	32
4*4	44	22	52	6	26	20	41	35	15	18	25
4*5	50	44	22	52	6	26	20	41	35	15	18
4*6+	106	146	176	182	217	204	211	211	233	246	239
3*1	0	5	7	9	9	11	10	11	11	12	12
3*2	0	0	5	7	9	9	11	10	11	11	12
3*3	12	0	0	5	7	9	9	11	10	10	11
3*4	20	12	0	0	5	7	9	9	11	10	10
3*5	21	20	12	0	0	5	7	9	9	11	10
3*6+	72	85	94	95	84	74	71	70	70	71	73
2*1	0	4	4	5	5	4	4	4	3	4	4
2*2	0	0	4	4	5	5	4	4	4	3	4
2*3	11	0	0	4	4	5	5	4	4	4	3
2*4	0	11	0	0	4	4	5	5	4	4	4
2*5	13	0	11	0	0	3	4	5	5	4	4
2*6+	37	43	36	40	34	28	27	26	26	26	26
1*1	0	1	2	1	2	1	1	1	1	1	1
1*2	0	0	1	2	1	2	1	1	1	1	1
1*3	12	0	0	1	2	1	2	1	1	1	1
1*4	0	12	0	0	1	2	1	2	1	1	1
1*5	0	0	10	0	0	1	1	1	1	1	1
1*6+	4	3	3	8	6	5	5	5	5	5	5

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APPENDIX S. CONSTRAINED EXPECTED INVENTORY AGAINST EXPECTED DEMAND OF NSGO PERSONNEL WHILE MAINTAINING THE "OUT" PROBABILITIES CONSTANT

EXPECTED TO HAVE AFTER OPTIMAZING EACH OF THE NINE SUB-MATRICES AND APPLYING THE MODEL AS DESCRIBED IN IV.D.1 AND 2										
Grades \ Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
9	249	270	303	343	386	408	430	450	464	463
8	244	231	225	223	240	250	263	284	311	331
7	588	580	550	531	507	484	465	449	439	430
6	418	401	409	408	396	381	368	355	342	329
5	339	331	337	336	335	333	334	334	333	331
4	278	269	266	255	234	215	200	187	172	159
3	129	135	141	148	157	165	172	177	181	183
2	47	40	33	31	31	30	29	29	28	29
1	15	14	10	10	9	8	7	6	6	5
EXPECTED TO HAVE AFTER ACCOMODATING ALL THE NINE SUB-MATRICES INTO THE NSGOTPM AND APPLYING EQUATION 4.5										
Grades \ Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
9	249	270	303	343	386	408	430	450	464	463
8	244	231	225	223	240	250	263	284	311	331
7	588	580	550	531	507	484	465	449	439	430
6	418	401	409	408	396	381	368	355	342	329
5	339	331	337	336	335	333	334	334	333	331
4	278	269	266	255	234	215	200	187	172	159
3	129	135	141	148	157	165	172	177	181	183
2	47	40	33	31	31	30	29	29	28	29
1	15	14	10	10	9	8	7	6	6	5
EXPECTED TO NEED										
Grades \ Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
9	662	662	662	662	662	662	662	662	662	662
8	745	745	745	745	745	745	745	745	745	745
7	677	677	677	677	677	677	677	677	677	677
6	378	378	378	378	378	378	378	378	378	378
5	334	334	334	334	334	334	334	334	334	334
4	206	206	206	206	206	206	206	206	206	206
3	85	85	85	85	85	85	85	85	85	85
2	33	33	33	33	33	33	33	33	33	33
1	10	10	10	10	10	10	10	10	10	10

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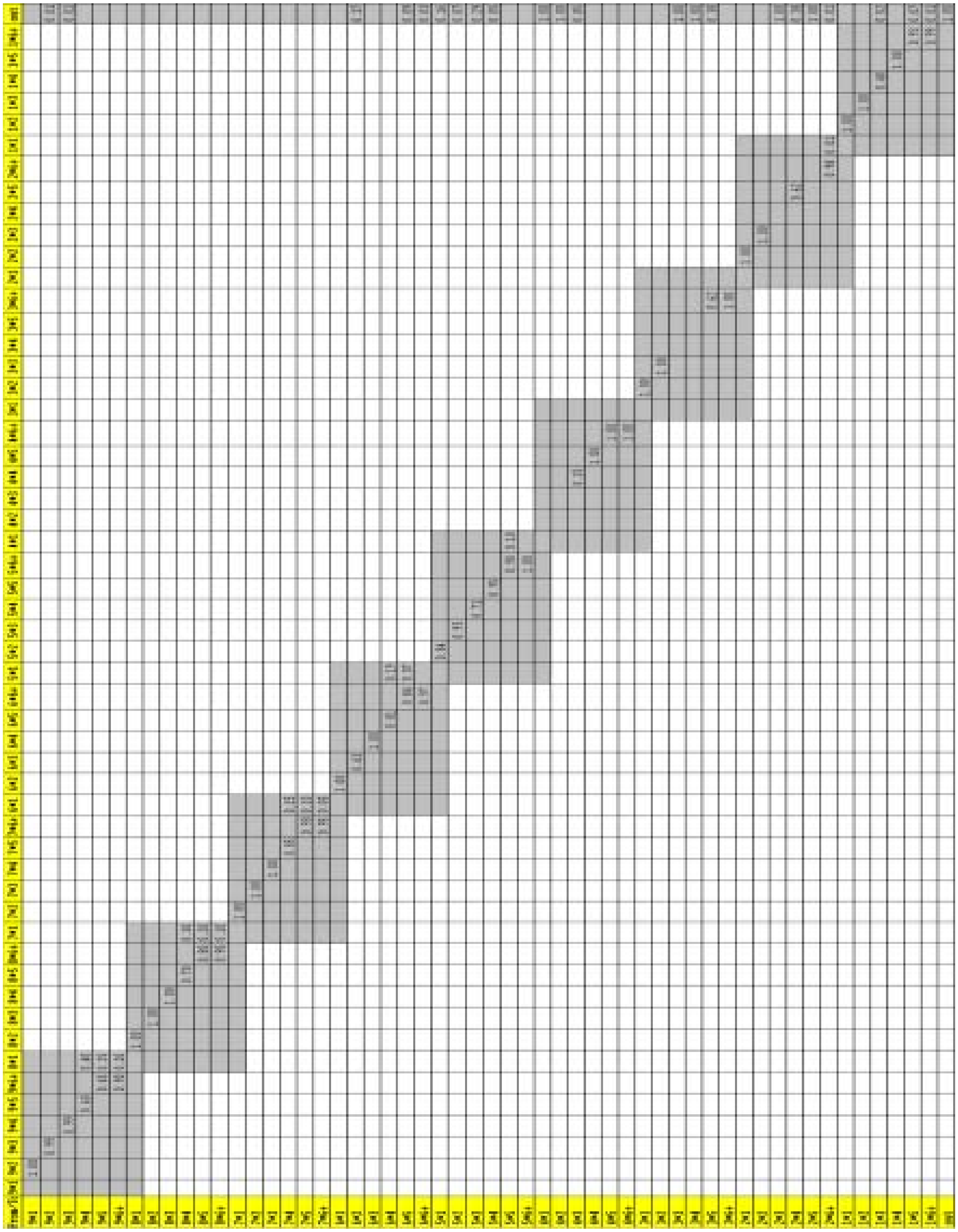
APPENDIX T. CONSTRAINED NSGOTPM WHILE CHANGING THE "OUT" PROBABILITIES



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APPENDIX U. CONSTRAINED ESTIMATED NSGO PERSONNEL DISTRIBUTION FROM 2003 THROUGH 2012 WHILE CHANGING THE "OUT" PROBABILITIES

Rank/Year	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
9*1	58	72	48	72	83	96	72	78	87	91	72
9*2	56	58	72	48	72	83	96	71	78	87	91
9*3	50	56	57	71	48	71	82	95	71	77	86
9*4	18	50	55	57	71	47	71	82	95	71	77
9*5	0	11	30	33	34	43	28	42	49	57	42
9*6+	4	4	10	29	47	65	86	96	114	134	158
8*1	46	8	24	34	37	45	40	47	57	66	62
8*2	59	46	8	24	34	37	45	40	47	57	66
8*3	67	59	46	8	24	34	37	45	40	47	57
8*4	97	67	59	46	8	24	34	37	45	40	47
8*5	0	68	47	41	32	5	17	23	26	32	28
8*6+	0	0	54	86	111	125	117	119	126	134	146
7*1	31	29	34	33	31	20	21	25	28	31	32
7*2	231	31	29	34	33	31	20	21	25	28	31
7*3	123	230	31	29	34	33	31	20	21	25	28
7*4	188	123	230	31	29	34	33	31	20	21	25
7*5	2	160	105	196	26	25	29	28	26	17	18
7*6+	19	20	163	249	412	415	417	422	425	428	421
6*1	19	29	35	53	37	28	28	29	28	27	26
6*2	176	19	29	35	53	37	28	28	29	28	27
6*3	119	109	12	19	22	34	23	17	18	18	18
6*4	71	119	109	12	19	22	34	23	17	18	18
6*5	10	58	97	89	10	15	18	27	19	14	15
6*6+	39	46	93	172	240	240	245	252	266	273	276
5*1	11	14	26	27	8	4	5	7	6	5	4
5*2	73	9	12	22	22	7	3	4	6	5	4
5*3	100	68	9	11	20	21	6	3	4	6	5
5*4	40	71	48	6	8	14	15	5	2	3	4
5*5	61	38	68	46	6	7	14	14	4	2	3
5*6+	83	138	172	233	273	279	285	297	310	314	316
4*1	6	6	4	7	5	1	1	1	1	0	0
4*2	52	0	0	0	0	0	0	0	0	0	0
4*3	23	0	0	0	0	0	0	0	0	0	0
4*4	44	3	0	0	0	0	0	0	0	0	0
4*5	50	44	3	0	0	0	0	0	0	0	0
4*6+	106	156	200	203	203	203	203	203	203	203	203
3*1	0	0	0	0	0	0	0	0	0	0	0
3*2	0	0	0	0	0	0	0	0	0	0	0
3*3	12	0	0	0	0	0	0	0	0	0	0
3*4	20	0	0	0	0	0	0	0	0	0	0
3*5	21	0	0	0	0	0	0	0	0	0	0
3*6+	72	85	85	85	85	85	85	85	85	85	85
2*1	0	0	0	0	0	0	0	0	0	0	0
2*2	0	0	0	0	0	0	0	0	0	0	0
2*3	11	0	0	0	0	0	0	0	0	0	0
2*4	0	0	0	0	0	0	0	0	0	0	0
2*5	13	0	0	0	0	0	0	0	0	0	0
2*6+	37	36	36	35	35	34	33	33	32	32	31
1*1	0	0	0	0	0	0	0	0	0	0	0
1*2	0	0	0	0	0	0	0	0	0	0	0
1*3	12	0	0	0	0	0	0	0	0	0	0
1*4	0	6	0	0	0	0	0	0	0	0	0
1*5	0	0	6	0	0	0	0	0	0	0	0
1*6+	4	4	4	9	9	9	9	9	9	9	9

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APPENDIX V. CONSTRAINED EXPECTED INVENTORY AGAINST EXPECTED DEMAND OF NSGO PERSONNEL. WHILE CHANGING THE "OUT" PROBABILITIES

EXPECTED TO HAVE AFTER OPTIMAZING EACH OF THE NINE SUB-MATRICES AND APPLYING THE MODEL AS DESCRIBED IN IV.D.1 AND 2										
Grades \ Year	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
9	250	273	310	355	405	435	465	494	517	526
8	247	238	239	245	271	290	312	341	376	406
7	593	591	570	564	557	549	546	545	550	555
6	380	376	380	381	376	376	377	378	379	379
5	337	333	343	337	332	328	331	333	334	335
4	210	207	210	208	204	204	205	205	204	204
3	85	85	85	85	85	85	85	85	85	85
2	36	36	35	35	34	33	33	32	32	31
1	10	10	10	10	10	10	10	10	10	10
EXPECTED TO HAVE AFTER ACCOMODATING ALL THE NINE SUB-MATRICES INTO THE NSGOTPM AND APPLYING EQUATION 4.5										
Grades \ Year	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
9	250	273	310	355	405	435	465	494	517	526
8	247	238	239	245	271	290	312	341	376	406
7	593	591	570	564	557	549	546	545	550	555
6	380	376	380	381	376	376	377	378	379	379
5	337	333	343	337	332	328	331	333	334	335
4	210	207	210	208	204	204	205	205	204	204
3	85	85	85	85	85	85	85	85	85	85
2	36	36	35	35	34	33	33	32	32	31
1	10	10	10	10	10	10	10	10	10	10
EXPECTED TO NEED										
Grades \ Year	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
9	662	662	662	662	662	662	662	662	662	662
8	745	745	745	745	745	745	745	745	745	745
7	677	677	677	677	677	677	677	677	677	677
6	378	378	378	378	378	378	378	378	378	378
5	334	334	334	334	334	334	334	334	334	334
4	206	206	206	206	206	206	206	206	206	206
3	85	85	85	85	85	85	85	85	85	85
2	33	33	33	33	33	33	33	33	33	33
1	10	10	10	10	10	10	10	10	10	10

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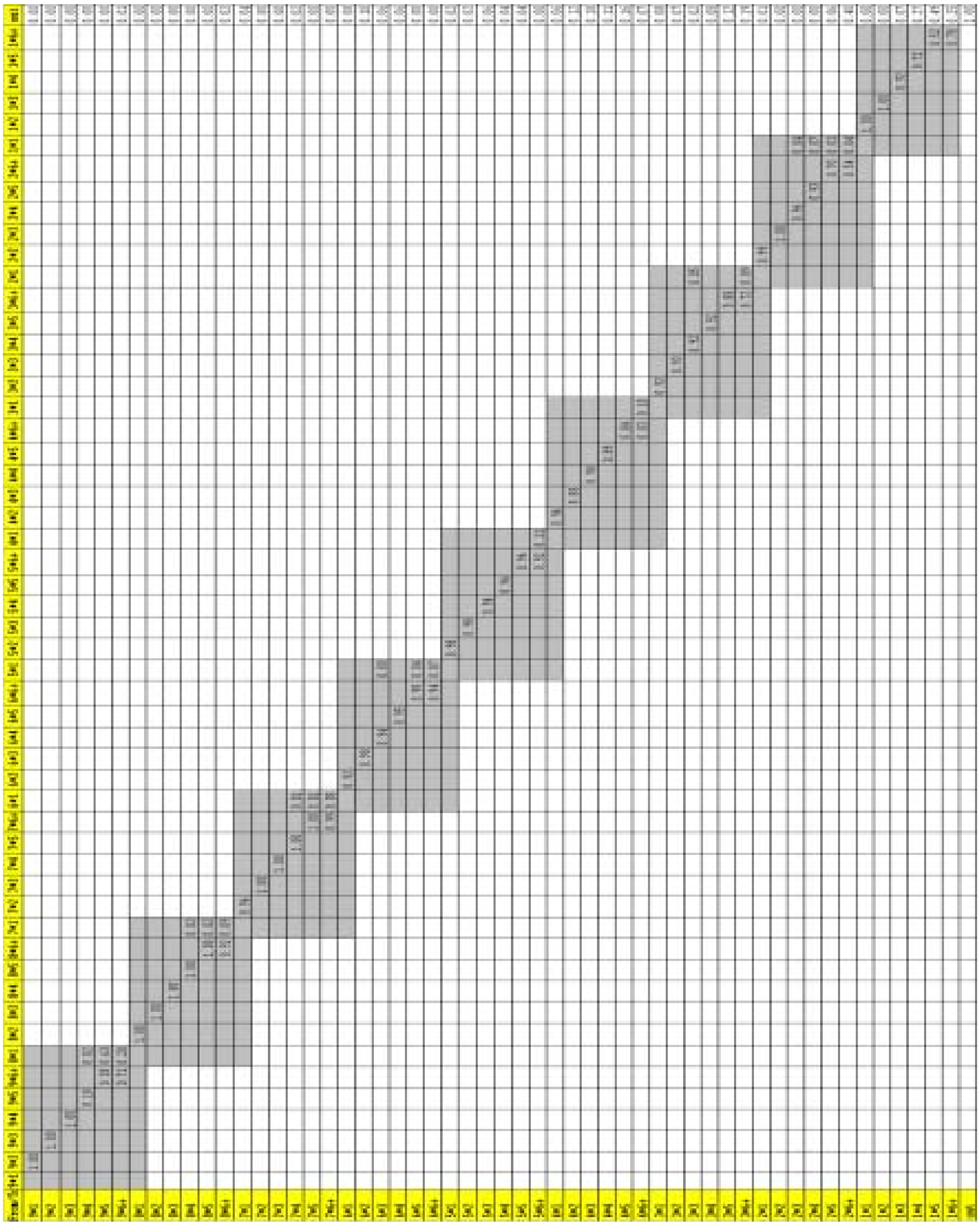
APPENDIX W. CONSTRAINED NSGOTPM WHILE CHANGING THE "OUT" PROBABILITIES AND THE PROBABILITY OF GRADUATING FROM THE NS



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APPENDIX X. CONSTRAINED ESTIMATED NSGO PERSONNEL DISTRIBUTION FROM 2003 THROUGH 2012 WHILE CHANGING THE "OUT" PROBABILITIES AND THE PROBABILITY OF GRADUATING FROM THE NS

Rank/Year	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
9*1	58	72	48	136	158	182	136	148	165	172	136
9*2	56	58	72	48	136	158	182	136	148	165	172
9*3	50	56	58	72	48	136	158	182	136	148	165
9*4	18	50	56	58	72	48	136	158	182	136	148
9*5	0	3	9	10	11	13	9	25	29	33	25
9*6+	4	3	3	6	8	10	12	12	18	23	29
8*1	46	16	44	52	55	68	50	120	147	172	138
8*2	59	46	16	44	52	55	68	50	120	147	172
8*3	67	59	46	16	44	52	55	68	50	120	147
8*4	97	67	59	46	16	44	52	55	68	50	120
8*5	0	97	67	59	46	16	44	52	55	68	50
8*6+	0	0	97	157	204	234	232	258	291	324	367
7*1	31	2	3	11	16	19	21	22	24	27	30
7*2	231	30	2	3	10	15	18	20	21	23	26
7*3	123	231	30	2	3	10	15	18	20	21	23
7*4	188	123	231	30	2	3	10	15	18	20	21
7*5	2	188	123	231	30	2	3	10	15	18	20
7*6+	19	21	209	329	556	579	574	571	574	582	594
6*1	19	3	3	12	16	25	26	26	26	26	27
6*2	176	17	3	3	11	15	23	24	24	24	24
6*3	119	158	16	2	3	10	14	21	22	22	22
6*4	71	111	148	15	2	3	9	13	20	20	20
6*5	10	67	105	140	14	2	3	9	12	19	19
6*6+	39	46	109	205	328	320	301	284	275	268	269
5*1	11	4	7	12	21	25	24	22	21	21	21
5*2	73	11	4	7	12	20	24	23	22	21	20
5*3	100	71	11	4	6	12	20	24	23	21	20
5*4	40	94	67	10	3	6	11	19	22	21	20
5*5	61	38	90	64	9	3	6	11	18	21	20
5*6+	83	135	162	236	280	267	250	236	228	228	231
4*1	6	9	15	18	26	31	29	27	26	25	25
4*2	52	6	9	14	17	24	29	28	26	24	24
4*3	23	46	5	8	12	15	22	26	24	23	22
4*4	44	21	41	4	7	11	13	19	23	22	20
4*5	50	39	18	37	4	6	10	12	17	20	20
4*6+	106	130	140	132	140	119	103	94	87	87	89
3*1	0	11	14	15	14	15	12	11	10	9	9
3*2	0	0	10	12	14	13	13	11	10	9	8
3*3	12	0	0	10	12	13	12	13	11	9	8
3*4	20	11	0	0	9	11	12	11	12	10	9
3*5	21	18	10	0	0	8	10	11	10	11	9
3*6+	72	70	67	57	41	30	28	29	30	31	32
2*1	0	7	7	6	6	4	3	3	3	3	3
2*2	0	0	7	7	6	6	4	3	3	3	3
2*3	11	0	0	7	7	6	6	4	3	3	3
2*4	0	11	0	0	7	6	6	6	4	3	3
2*5	13	0	10	0	0	7	6	6	5	4	3
2*6+	37	32	18	19	10	6	9	10	11	11	9
1*1	0	2	2	1	1	1	1	1	1	1	1
1*2	0	0	2	2	1	1	1	1	1	1	1
1*3	12	0	0	2	2	1	1	1	1	1	1
1*4	0	11	0	0	2	2	1	1	1	1	1
1*5	0	0	8	0	0	1	1	1	1	1	1
1*6+	4	3	2	6	5	4	4	4	3	3	3

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APPENDIX Y. CONSTRAINED EXPECTED INVENTORY AGAINST EXPECTED DEMAND OF NSGO PERSONNEL. WHILE CHANGING THE "OUT" PROBABILITIES AND THE PROBABILITY OF GRADUATING FROM THE NS

EXPECTED TO HAVE AFTER OPTIMAZING AT ONCE THE NSGOTPM AND APPLYING THE MODEL AS DESCRIBED IN IV.F										
Grades \ Year	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
9	242	246	330	433	547	633	660	678	678	676
8	285	328	373	417	469	501	604	732	881	995
7	594	597	605	617	628	642	656	673	693	715
6	403	384	377	375	376	377	378	378	380	381
5	354	340	333	332	334	335	335	334	334	333
4	250	228	212	206	206	206	206	204	202	199
3	111	101	94	89	88	88	86	82	79	75
2	50	41	39	36	35	34	32	30	28	26
1	16	15	11	11	10	9	8	8	8	7
EXPECTED TO NEED										
Grades \ Year	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
9	662	662	662	662	662	662	662	662	662	662
8	745	745	745	745	745	745	745	745	745	745
7	677	677	677	677	677	677	677	677	677	677
6	378	378	378	378	378	378	378	378	378	378
5	334	334	334	334	334	334	334	334	334	334
4	206	206	206	206	206	206	206	206	206	206
3	85	85	85	85	85	85	85	85	85	85
2	33	33	33	33	33	33	33	33	33	33
1	10	10	10	10	10	10	10	10	10	10

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